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All communications should be addressed to the Editor.

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Notices of the Royal Aëronautical Society.

Election of Members.

The following members were elected in the various grades, as shown, at a Council Meeting held on March 16th:—

Fellow.—G. Tilghman Richards.

Associate Fellows.—B. Campbell, D. H. Kennedy, Miss E. D. Lang, J. S. Nicholson, W. E. Nuttall, C. I. R. Campbell, M. H. Spencer, H. S. Wildeblood.

Members.—E. E. G. Adams, E. S. Wicks, D. C. S. Evill, E. C. Vivian.

Associate Member.—F. W. Verry.

Students.—T. A. Kirkup, E. H. Mansbridge.

Examinations.

The following Committee has been appointed to draft the rules and regulations for examinations for Associate Fellowship:—Wing Commander T. R. Cave-Browne-Cave (Chairman), Major Low, Messrs. Piercy, Pritchard and Pippard, and Dr. Walmsley.

Educational Lectures.

Arrangements have been made for the delivery under the auspices of the Society of a series of six lectures on "The Selection and Treatment of Special Materials used in Aircraft" to the students of Sheffield University, commencing in October. The Chairman, Brigadier-General R. K. Bagnall Wild, will inaugurate the series.

Wilbur Wright Lecture.

His Royal Highness Prince Albert has graciously consented to take the chair at the Wilbur Wright Lecture, which will be held at the Central Hall, Westminster, on Tuesday evening, June 22nd.

Transactions.

The second of the "Transactions of the Royal Aeronautical Society," is now available and copies may be obtained at the Society's offices, price 5s. each. The paper is entitled "Position Fixing in Aircraft During Long-Distance Flights over the Sea," the Authors being Instructor Commander T. Y. Baker, R.N., and Major L. N. G. Filon, Fellow. It constitutes the only authoritative work at present issued on astronomical navigation in aircraft.

Library.

Owing to the approach of summer it has been decided to close the Library on Saturday afternoons, and this will therefore henceforward be available for the use of members between the hours of 10 a.m. and 12.30 p.m. only on that day. It will, as formerly, be open from 10 o'clock to 5 on other week-days.

Affiliated Societies.

An application for affiliation from the Cambridge University Aeronautical Society has been acceded to.

Aerial Navigation in the Antarctic.

An application has been received from the British Imperial Antarctic Expedition for assistance in connection with the proposal to use aeroplanes on survey work with the Expedition. The Council have, in reply, offered to assist by advising on the types of aircraft most likely to prove suitable, and on the technical equipment and details generally. It is proposed to carry out preliminary experiments in the Arctic regions over a period of twelve months before sending any machines to the Antarctic.

It is felt that Mr. J. L. Cope's proposed lecture on "Aerial Survey in the Antarctic" would prove of enhanced interest if it contained the results of the deliberations of the special committee of the society to be appointed, by the request of the British Imperial Antarctic Expedition, to advise on the plans and details of the proposed use of aeroplanes in connection with the expedition. At Mr. Cope's request the lecture, which was to have taken place on Wednesday evening, April 7th, has therefore been postponed to a date which will be announced later.

Representation of Other Bodies.

In response to an invitation from the Air Ministry, Mr. Alec Ogilvie, Fellow, has been nominated to represent the Society on the new Aeronautical Research Committee, which is taking the place of the Advisory Committee on Aeronautics.

International Aero Exhibition.

In response to a request from the Society of British Aircraft Constructors, the patronage of the Society has been accorded to the forthcoming International Aero Exhibition at Olympia in July next. It is hoped to arrange for a room to be provided for the use of members during the show.

Aerial League.

An invitation has been received from the Aerial League to nominate two representatives of the Society, of whom one shall be the Chairman *ex-officio*, to the reconstituted Committee of the League. The invitation has been accepted.

Scottish Branch.

Arrangements have now been completed for the formation of the Scottish Branch, which already numbers 146 members. Details will be found in the Council's Annual Report printed elsewhere in this issue.

No. 1 Aircraft Cadet Training Wing.

The Society has been informed by No. 1 Aircraft Cadet Training Wing that it is proposed to have a limited number of Technical Cadet Sergeants in charge

of evening instructional classes on aero engines, aeroplane rigging, wireless, etc., which posts it is proposed to offer in the first instance to students of the Royal Aëronautical Society. Any student wishing to apply for one of these posts should write, mentioning that he is a student member of this Society, to the Officer Commanding, No. 1 Aircraft Cadet Training Wing, 25, Camden Road, N.W.

Lectures.

The following are the details of the papers to be read before the Society during the remainder of the present Session :—

Wednesday, April 14th, Royal Society of Arts, 8 p.m.—"Trans-Continental Flying," by Captain P. D. Acland, Major-General E. D. Swinton, C.B., D.S.O., in the chair.

Wednesday, April 28th, Royal Society of Arts, 8 p.m.—"Aerial Transport from the Business Point of View," by Major-General Sir Sefton Brancker, K.C.B., Major G. C. Tryon, Under-Secretary of State for Air, in the chair.

Wednesday, May 12th, Royal Society of Arts, 8 p.m.—"A Comparison of the Cost of Air-Ton Miles with other forms of Transport," by Lord Montagu of Beaulieu, C.S.I., V.D., D.L., M.P.

Wednesday, May 26th, Royal Society of Arts, 8 p.m.—"Some Points of Importance in the Work of the Advisory Committee for Aeronautics," by Sir Richard Glazebrook.

Wednesday, June 22nd, Central Hall, Westminster.—"Wilbur Wright Memorial" Lecture, by Commander Hunsaker, U.S.N., H.R.H. Prince Albert in the chair.

New Rates of Subscriptions.

Members are requested to note that the rates of subscriptions have now been altered as follows :—

Grade.	Entrance Fee.	Subscriptions.	
		Elected to the Society in any grade prior to June 1st, 1920.	Elected subsequent to June 1st, 1920.
Fellow	£5 5 0	£5 5 0	£6 6 0
Associate Fellow ...	3 3 0	3 10 0	4 4 0
Student	—	1 1 0	1 1 0
Member	1 1 0	3 3 0	4 4 0
Associate Member ...	—	1 10 0	2 2 0
Founder Member ...	—	1 10 0	2 2 0
Foreign Member ...	—	1 10 0	2 2 0

These rates will come into force immediately and members are requested to forward the additional amount for the current year due in each case.

Obituary.

The death of Mr. W. H. Lyne, Associate Fellow, on March 12th, 1920, is announced with regret. Mr. Lyne was elected a member in May, 1917, and an Associate Fellow in February, 1919.

The Council have sent an expression of deep sympathy to the widow.

W. LOCKWOOD MARSH, *Secretary.*

THE ROYAL AERONAUTICAL SOCIETY.

Council's Report, 1919-1920.

In presenting the 55th Annual Report the Council has the honour to announce that during the year His Royal Highness the Prince of Wales, K.G., graciously consented to become the Patron of the Society. The Right Honourable the Lord Weir of Eastwood has agreed to become President. The Council for the year consisted of the following members :—

Chairman : Brigadier-General R. K. Bagnall Wild, C.M.G., C.B.E.

Vice-Chairman : Major-General R. M. Ruck, C.B., C.M.G.

Mr. L. Bairstow, F.R.S., Mr. A. E. Berriman, Mr. F. H. Bramwell, Lieut.-Col. A. G. Burgoyne, M.P., Wing Comm. T. R. Cave-Browne-Cave, C.B.E., Sir Mackenzie Chalmers, K.C.B., C.S.I., Sir Robert Hadfield, Bt., F.R.S., Col. Sir Capel Holden, K.C.B., Major A. R. Low, D.Sc., Lieut.-Col. M. O'Gorman, C.B., Mr. A. Ogilvie, C.B.E., Mr. F. Handley Page, C.B.E., Mr. H. White Smith, Major R. V. Southwell, Dr. T. E. Stanton, F.R.S., Lieut.-Col. H. T. Tizard, Mr. G. Holt Thomas, Dr. R. Mullineux Walmsley.

The Council feel that they are voicing the opinion of all the Members when they express their grateful appreciation of the services of General Ruck during his tenure of office as Chairman over a period of eight years.

The past year has resulted in a considerable augmentation of the prestige of the Society, which continues to take a leading part in the development of aeronautics. The Council desire to call attention to the financial position which, in common with that of other similar bodies, is somewhat difficult owing to the general all-round increase in prices and depreciation of currency value. Any increase in activities is somewhat hampered by the financial position and the Council desire to appeal to members to come forward with assistance in order that the Society may take up the question of the provision of adequate educational facilities throughout the country, which is considered to be the most useful sphere in which a society of this nature can be engaged, and that the free issue of the Journal, which will increase in interest and value, may be preserved as a permanent record of the Society's work.

Membership.

In January, 1919, the membership of the Society was 1,045, and this increased during the year to 1,146.

Branches.

A large Scottish branch has been formed with its headquarters in Glasgow, sub-branches being in process of formation at Edinburgh, Aberdeen, and Dundee. The membership stands at 146, Members and Associate Members being elected by the Scottish Executive Committee, while the Council in London elect all Fellows and Associate Fellows. The Scottish Branch remit to the main Society 50 per cent. of all subscriptions and conform to the rules in force for the time

being. A number of lectures have been already delivered in Scotland, and during the coming year the Scottish Branch will doubtless become a large and important body.

A request which has been received from the Cambridge University Aeronautical Society for affiliation to the Society has been acceded to.

Aeronautical Research Committee.

The Advisory Committee for Aeronautics is being replaced by a new Government body known as the Aeronautical Research Committee, to which the Society has been invited by the Air Council to nominate a representative. Mr. Alec Ogilvie, C.B.E., was therefore elected as the Society's representative. Dr. R. Mullineux Walmsley has been similarly elected to the Advisory Committee of Aeronautical Education formed by the Imperial College of Science and Technology.

The Technical Terms Committee.

The Technical Terms Committee has continued to meet regularly, continuing the revision of the terms of the Glossary as at present printed. A French translation of the Glossary by Captain Plugge, Fellow, has been adopted by the Air Ministry and is being officially printed by the Stationery Office, for the use of the Inter-Allied Aeronautical Commission, the Society retaining its copyright.

Lectures.

Lectures in various centres of the country are under consideration with a view to disseminating knowledge of, and interest in, the science of aeronautics. Arrangements have been made for a course of six lectures on the Selection and Treatment of Special Materials used in Aircraft to the students of Sheffield University, and a similar course is also under consideration for the Bradford Technical College.

Meetings.

The lectures delivered before members have continued to increase in interest, advantage having been taken of the absence of censorship and the release of confidential information by the Air Ministry to disseminate in this way the latest knowledge on the various aspects of aeronautical science and engineering. The increase in interest has been accompanied by a considerable augmentation in the number of persons, particularly visitors, present at each lecture.

The Council desire to acknowledge the kindness of Brigadier-General R. K. Bagnall Wild, Air Commodore E. M. Maitland, Lieutenant-Colonel M. O'Gorman, Wing Commander T. R. Cave-Browne-Cave, Mr. H. White Smith, Lieutenant-Colonel H. T. Tizard and the Master of Sempill in presiding at the various meetings. The Council also offer their most cordial thanks to Sir Horace Darwin, Dr. C. Atkin Swan, Mr. Griffith Brewer, Mr. J. D. North, Major H. E. Wimperis, Mr. A. P. Cole, Squadron Leader J. E. M. Pritchard, Major Percy Bishop, Professor B. Melvill Jones, and Major C. F. Abell, for the series of admirable papers read before the Society.

The " Wilbur Wright " Lecture.

This lecture was held at the Royal Society of Arts on June 18th, 1919, when Mr. L. Bairstow read a Paper on " Progress of Aviation During the War Period." Major-General R. M. Ruck presided.

Secretary.

The Council desire to acknowledge the work done during his three years' tenure of office by Mr. W. Barnard Faraday, who resigned the Secretaryship in October. The announcement of the vacancy resulted in 41 applications, Lieutenant-Colonel W. Lockwood Marsh being finally selected to fill the post. The new Secretary entered upon his duties on January 1st, 1920.

The Council desire to acknowledge with appreciation the invaluable assistance given to the Society by the indefatigable work of Miss O. St. Barbe, Assistant Secretary.

Qualifications for Membership.

The question of qualifying examinations has been again considered, and the Council have resolved that it is desirable that examinations for Associate Fellowship should be instituted at once. A Committee consisting of Wing Commander Cave-Browne-Cave (Chairman), Major Low, Messrs. Piercy, Pritchard and Pippard and Dr. Walmsley, has therefore been appointed to draw up draft rules and regulations.

Finance.

The Council report that the past year's working has resulted in a deficit, as shown in the accompanying Balance Sheet, of £1,780. Of this, £450 is due to loss on the Journal, and £450 to expense in the production of pamphlets (including the Glossary of Aeronautical Terms), reprints, etc. A donation of £650 was made to the late Secretary on his retirement, and the balance is due to general increase in the cost of printing, etc. Against this may be set a surplus balance of £718 carried forward from the year 1918, leaving a nett deficit of £1,060. To assist in meeting this it has been decided to sell War Loan to the extent of £750.

The Council feel that it is necessary to effect economies in working and provide for increased income unless a further deficit is to be incurred. It is estimated that a reduction on last year's expenditure to the extent of in all £1,000 will be effected; against which must be set inevitable increased expenses of salaries, etc., amounting to £500. Detailed proposals for raising subscriptions to meet the situation are contained in resolutions to be moved by the Council.

The Journal.

The experiment of issuing the Journal as a monthly has been continued, and is giving satisfactory results. Owing to further increase in the cost of production it has been found necessary to raise the price to non-members from 2s. 6d. to 3s. 6d. The financial position should not be allowed to interfere with the production of the Journal as it constitutes a full and complete record of progress in the science of aeronautics.

Transactions.

During the year a commencement was made of the publication of papers of a fundamental character on various aspects of aeronautical science in a series to be known as "Transactions of the Royal Aeronautical Society." The following have been published:—No. 1, "The Calculations of Stresses in Wing Spars," by A. Berry. No. 2, "Position Fixing in Aircraft During Long Distance Flights Over the Sea," by Instructor-Commander T. Y. Baker, R.N., and Major L. N. G. Filon, Fellow.

Ground Engineers.

In connection with commercial aviation the Air Ministry has instituted the technical grade of " Ground Engineers " who are licensed by the Government to carry out the duties of ensuring that machines employed in commercial aviation are airworthy before flight. It is felt that the Society can be of great assistance to these gentlemen, and steps are being taken to ascertain how this can best be done.

Editor.

The Council desire to thank Mr. J. L. Pritchard, Associate Fellow, for consenting to act as Editor of the Journal and Transactions at a nominal salary.

Honorary Officials.

The Council desire to express their most cordial thanks to Mr. B. Woodward, the Honorary Solicitor, who has advised them throughout the year, and to Mr. A. E. Turner, who has consented to act as Honorary Treasurer.

PROCEEDINGS.

SEVENTH MEETING, 55th SESSION.

The Seventh Meeting of the Fifty-Fifth Session was held in the Hall of the Royal Society of Arts, London, on Wednesday, February 4th, 1920, Air Commodore B. M. Maitland occupying the chair.

The CHAIRMAN said it was his very pleasant duty to introduce Squadron Leader Pritchard. Before the war Squadron Leader Pritchard was a successful and very efficient mining engineer, and when the war broke out he at once joined up with the Royal Naval Air Service for duty with airships. He had always had a keen enthusiasm for airships. His war record was an extremely good one, and one to be very proud of. He first of all went to Gallipoli and did some active service flying, and he then came back to England and did more flying in different types of airships. He was finally specially selected to serve on the Airship Headquarters on very important duties in connection with accepting airships as they were built for service in the Air Force. Each airship when completed—when it left the designers and constructors—had to be " vetted " and given a bill of health and certified as efficient and suitable for the flying duties it had to perform. In selecting an officer to carry out these important duties an officer had to be found who had not only an all-round flying experience, but at the same time first-rate technical knowledge, and in Squadron Leader Pritchard that man was found. In connection with those duties Squadron Leader Pritchard took part in every trial flight in all rigid airships built in this country during the last few years. For these important duties and for his brilliant services he had quite recently been awarded the Air Force Cross. He has a very magnetic personality. His cheery optimism and sense of humour have endeared him to all in the Airship Service. His laugh is so infectious that one has to join in when hearing it. He was afraid they might not hear it that evening, as Squadron Leader Pritchard might regard that as a grim entertainment, but perhaps later on in the proceedings they might be more lucky. That reminded him of an amusing incident that happened in connection with the R.34 when landing in Minneola in America. Their landing officer, Major Fuller, had had to go off to Boston as the result of a distress signal from R.34 saying she might be compelled to land there. Major Scott was running out of petrol and things looked rather gloomy at one moment. They managed to make Minneola, however, and discovered that there was no landing officer there, and it became necessary to supply a landing officer from the ship. Squadron Leader Pritchard volunteered, and he was bundled out of the front window of the car with a parachute, and looking down from the car, a thousand feet above, he appeared to make a rather upside down landing. It was certainly a heavy landing. Some reporters rushed up to ask his impressions of his parachute landing. He pointed to the dent in the ground that his unfortunate and fragile body had made, and left it to them to work out. He could, however, claim to be the first individual to land on American soil by way of the air and might be regarded as our aerial Columbus, although the first Columbus presumably landed in a sedate and dignified manner on the flat of his feet and their aerial Columbus landed in hardly a dignified or sedate manner on the flat of his back. He would now ask their lecturer to get right ahead with his lecture, which he was sure would be extremely interesting.

Squadron Leader J. E. M. PRITCHARD then delivered the following lecture :—

RIGID AIRSHIPS AND THEIR DEVELOPMENT.

Introduction.

This paper has been prepared as a continuation to the very interesting general airship paper read before the Royal Aëronautical Society by Wing-Commander T. R. Cave-Brown-Cave. An attempt has been made not so much to describe in detail the various parts of a rigid airship as to discuss along broad lines the underlying requirements and problems and the difficulties facing future development. It is hoped that this paper will also serve as an introduction to further papers dealing with specialised parts of the general subject "Rigid Airships," such as mooring, fabric, machinery installations, etc.

When considering problems connected with future technical development, it is in the first instance necessary to realise clearly the scope and functions of the operational requirements, and thus to provide a sound basis from which to start. The first problem to consider in this connection is the difference between military and commercial requirements. The chief military functions of the rigid are extended and fast patrol, convoy and scouting duties. The commercial function is rapid long distance transport. The question of the amount of present and future divergence between military and commercial rigids is also of the greatest importance. The commercial airship has not yet been developed at all in this country, and only to a limited extent in Germany. There is no doubt that in time the commercial rigid will differ materially from the military rigid, though probably not to the same extent as warships differ from merchant craft. For the next four or five years, however, the two types of rigids will only diverge from their common point of origin to such a very limited extent that either type will be readily and rapidly convertible from one to the other.

The Air Ministry, appreciating that the information acquired during the war by the expenditure of public money should now be available for furthering the pursuits of peace, has kindly allowed much information of an official nature to be included in this paper.

Hull.

Of the three main parts of a rigid, namely, the hull structure, the propelling machinery, and the fabric items, such as the outer cover, gasbags, etc., the hull structure is at the present time by far the most satisfactory from an operational standpoint.

The construction of the hull, and the functions of its component parts, have already been discussed by the Royal Aëronautical Society, and it is, therefore, proposed to devote this part of the paper to an examination of such problems as the streamline form of the hull, speed, endurance and weight-carrying capacity, the effect of size on performance, etc. Figs. 1, 2 and 3 show clearly the change in the form of the hull during recent years. The blunt tail and the length of the parallel portion and large stabilising area are particularly noticeable in the early types. Great strides were made by the Germans when they evolved the 33 class streamline form; its main characteristics are a very fine tail, short parallel portion, and small stabilising area. The length/diameter ratio of this form is 8 compared with 10 for the parallel-sided 23 class.

Form.

The head resistance of an airship of a given capacity can, broadly speaking, be considered under three heads:—

(1) The small portion due to and proportional to the area of the maximum cross section of the hull.

(2) The large portion due to skin friction of the hull and proportional to the surface area.
(3) Appendage resistance, or resistance of the fins, cars, external wires, struts, etc.

Naturally, the greater the diameter of the hull in proportion to its length the smaller will be the surface area for a rigid of a given capacity, and consequently the resistance to its passage through the air due to skin friction will be reduced; on the other hand, the portion of head resistance due to cross sectional area will be increased. There is, therefore, a point at which the combined resistance due to these two conflicting causes will be a minimum. This point appears to be reached with hulls of a length/diameter ratio of about 6. Although the size of the hull is large compared with the size of the various appendages, wires, struts, etc., which are considered under the general head of appendage resistance, nevertheless, this resistance is, for the early parallel-sided rigids, in the order of 40 per cent. of the total combined resistance of the airship, and for modern rigids in the order of 30 per cent. It will, therefore, be seen that very careful attention must be given to reducing, by every possible means, the parasitic resistance as well as to improving the streamline form of the hull.

The form of the hull of a rigid airship must be a compromise. The smaller the length/diameter ratio, or the more nearly spherical the form, the lighter will be the structure. On the other hand, after a certain point, *i.e.*, wherever the ratio length/diameter is less than about 6, the higher will be the head resistance and the greater will be the weight of the machinery necessary to drive the airship through the air at a given speed.

From these two considerations the following axiom can be developed:—The longer the distance a rigid of a given size is required to fly, *i.e.*, the greater the percentage of its disposable lift needed for fuel, the greater will be the economy in obtaining a true streamline form with low head resistance even at the expense of a certain amount of lift. On the other hand, if an airship is only required to fly a short distance, the greater weight-carrying capacity more than offsets the greater fuel consumption of the short ship of large diameter.

Size.

The effect of size on performance is of fundamental importance, and has a marked bearing on all future development.

In airships of similar form, but of different size, the total lift varies as the (linear dimensions)^3, being proportional to the total volume of the gas contained in the gasbags. This should be clearly distinguished from the lift of an aeroplane which is proportional to the area of the wing surfaces and therefore varies as the (linear dimensions)^2, while with airships, as already stated, the lift varies as the (linear dimensions)^3.

Generally speaking, with increase in size, the weight of such items as fins and planes increases more or less proportionately to the volume. The hull structure fabric and cars, however, can be confidently predicted to increase in weight with increase in size at a rate distinctly less than the (linear dimensions)^3. The remaining item, however, the propelling installation, shows the most marked percentage saving in weight in proportion to increase in size. This is a matter of great importance as, in a rigid of 2,000,000 cu. ft. capacity and maximum speed 80 miles per hour, the weight of the propelling installation is as much as one-third of the total fixed weight of the ship.

The head resistance of an airship, and consequently the B.H.P. necessary to drive it through the air at a given speed, is roughly proportional to the (linear dimensions)^2. It therefore follows for a given speed that with increase in size the ratio weight of machinery/gross lift only increases as the (linear dimensions)$^{-1}$, in

other words, inversely as the linear dimensions. Besides this very material saving in percentage weight of the machinery installation with increase in size, a corresponding economy in petrol consumption is attained, which is of far greater importance, as in the large modern rigids the petrol capacity is well over five times as great as the total machinery weights. This definite improvement in performance with increase in size does not allow for a still further probable improvement, which can be predicted with the greatest confidence due to general refinements in design and more skilful use of materials.

This gain in performance with increase in size is shown practically in the accompanying table by comparing the range of a 10,000,000 cu. ft. capacity rigid with a similar ship of 2,000,000 cu. ft. capacity. In both cases a disposable lift of 60 per cent. and a maximum speed of 75 m.p.h. have been arbitrarily assumed. Even though the gain in range at a constant speed of the 10,000,000 cu. ft. ship is very marked in the example, a still further gain would be obtained in practice by the larger ship because it would actually possess a larger percentage of disposable lift than the small ship.

PERFORMANCE TABLE.

		Rigid of 2 Million c.f. Capacity.	Rigid of 10 Million c.f. Capacity.
Length		645 ft.	1,100 ft.
Diameter		79.5 ft.	135.5 ft.
Gross Lift (at 68lbs./1,000 cub. ft.)		60.7 tons.	303.6 tons.
Disposable Lift (60% Gross Lift)		36.4 tons.	182.2 tons.
Crew, Ballast, Food, etc. (15% Gross Lift)		9.1 tons.	45.5 tons.
Dischargeable Lift (45% Gross Lift)		27.3 tons.	136.6 tons.
Maximum Speed		78 m.p.h.	78 m.p.h.
70 M.P.H. (Normal full speed)	*Max. Range ...	67.9 hours. 4,125 naut. miles 4,750 stat. ,,	115.5 hours. 6 950 naut. miles. 8,000 stat. ,,
	†H.P. developed	1,700.	5,000.
45 M.P.H. (Comparison Speed)	*Max. Range ...	218 hours. 8,530 naut. miles 9,820 stat. ,,	364 hours. 14,200 naut. miles. 16,400 stat. ,,
	†H.P. developed	530.	1,580.

* Fuel and Oil Consumption has been taken on the basis of .53 lbs. per B.H.P. hour.
† Thrust H.P. has been taken as equal to 70 % of B.H.P. of full speed, and 60 % at 45 m.p.h.

If the question of streamline form and size of ship is studied from the point of view of carrying with the utmost economy unit weight unit distance at unit speed, it will be found that the greatest economy is effected if a ship is designed with the most perfect streamline form available and of such size that the normal

range of the ship is a little over twice the distance between the two termini between which it is proposed to fly, allowance being made when estimating the normal range for the necessary safety margin of fuel.

It can, therefore, be stated definitely that for Service requirements, where high speed and high performance are of the greatest importance, the most perfect streamline form available is required, and that the size of the ship will vary according to the performance required. For commercial airships the same also applies, and the best possible streamline form should be used whatever the variation in distance between the termini, the factor to be varied being the size and not the form of the ship.

These axioms are, of course, only general, and may be modified to a certain extent, for example, when the housing sheds are not of sufficient size and the ships have to be modified from the ideal streamline form to get the best performance out of, for example, a low shed. In general, the cramping effect of too small housing sheds has been very acutely felt, and has tended towards the production of rigids with a large amount of parallel portion.

Unfortunately, the question of streamline form is one of considerable difficulty, and although many experiments have been carried out in wind tunnels, owing to the very large scale difference between the actual ship and the model, the data obtained is at present of a vague and somewhat unsatisfactory nature. Recent results, however, are most encouraging. Up to a short time ago the R.33 streamline form, a copy of the German L.33 form, was considered about as efficient as could be obtained and far in advance of the previous parallel-sided ships built by the Germans and by this country. Certain changes in streamline form have, however, been instituted in R.38 design, whereby it has been found possible to increase the lift by about 6 tons more than if the ship had been of the 33 streamline form with only a very small increase in weight of structure and without, it is hoped, appreciably increasing the head resistance. If this proves to be the case, the advantage is obvious. There is now every reason to believe that a streamline form of appreciably lower length/diameter ratio can be developed with an even lower head resistance than that of the R.33 streamline form, this ratio being reduced from 8 to 6, or even lower.

It is possible at the present time to construct ships of the R.33 streamline form with an efficiency ratio, *i.e.*, disposable lift/gross lift, of some 60 per cent. and a maximum speed of over 75 m.p.h. for ships of under 2,500,000 cu. ft. capacity. If the experimental model results are justified and a streamline form is obtained of equally low or lower head resistance with a length/diameter ratio of 6 or under, it is quite reasonable to suppose that the ratio disposable lift/gross lift can be increased to nearly 70 per cent. without loss of speed or range. These theories appear to be confirmed by fact in the case of the German commercial airship the "Bodensee," which appears to be of far more dumpy outline than the 33 streamline form, and as far as her weight-carrying capacity, range and speed are concerned, having regard to her very small size, appears to have the highest performance of any rigid yet built.

Speed.

The speed for any given airship is proportional to the $(\text{H.P.})^{\frac{1}{3}}$. The machinery weights are proportional to the horse-power and the speed is, consequently, proportional to the $(\text{machinery weights})^{\frac{1}{3}}$. A point, therefore, is rapidly reached at which it is no longer practical to increase the speed of the ship, owing to the large reduction in disposable lift per unit increase in speed. A reasonably high speed, in the order of 80 m.p.h., is, however, essential because the whole justification for the use of airships is, in the case of Service requirements, rapid and extended reconnaissance and patrol duties, and for commercial purposes reliable and fast transport over long distances.

Naturally, it is of the greatest importance to obtain a streamline form of particularly low head resistance when speeds of over 40 m.p.h. are required. A reasonable amount of speed is also an economy, taking into consideration adverse winds, since, in practice, a ship with a large reserve of speed can be flown between any two points at a given speed with a smaller safety allowance of spare petrol than a low speed ship, when the given speed is nearly her maximum speed. Up to a point the smaller safety margin of petrol necessarily counterbalances the dead weight of the extra machinery. Very much greater reliability is also achieved in the event of one or more engines breaking down.

There are several important speeds which can with advantage be defined :—

(1) The speed below which it is impracticable to fly, owing to the necessity for jettisoning ballast. This speed varies according to weather conditions. In the mornings and evenings, owing to superheating effects, this speed must necessarily be in the order of at least 45 m.p.h. under normal conditions. For a few hours before dawn, when the ship is probably more or less in equilibrium, it can naturally be flown at a very much lower speed. With increase in size this speed tends to increase approximately as the (dimensions) $^{3/2}$ as explained under the heading of dynamic lift.

(2) Theoretical economic speed depends directly on the speed and direction of the wind. This is, in practice, usually determined by the Scott construction as shown (Fig. 4). With a favouring wind in the same direction as the path of the ship the theoretical economic speed is zero, and with a head wind the theoretical economic speed is given by the formula :—

$$E = \frac{WN}{N - 1}$$

where E = economic speed.
W = speed of the wind.
N = the power at which the petrol consumption increases with speed.

The figure N for ships of the 33 class is in the order of 2.6, owing to loss of propeller efficiency at low speeds.

(3) Practical Economic Speed.—This speed is generally greater than the theoretical speed, owing to temperature effects tending to make the ship light or heavy and to the fact that most winds are of a comparatively local nature. If reasonable meteorological information is available, it is generally possible, by flying at high speed for a few hours, to get into a more favourable wind area, which, in practice, generally gives greater fuel economy than if the ship had been flown for the whole time at the theoretical economic speed.

(4) Standard speeds : Four speeds have been laid down as standard for convenience in preparing performance tables.

(*a*) *Maximum speed*: The greatest speed the ship can maintain for a short period with all engines running at full throttle.

(*b*) *Normal full speed* = 90 per cent. maximum speed. Having regard to the prime movers available during the next few years, normal full speed is assumed to be the highest speed at which the ship can run continuously on all engines.

(*c*) *Cruising speed* = 80 per cent. maximum speed. This speed is assumed to be the normal speed at which the ship would fly with engines giving the same revolutions as for normal full speed, but having regard to

the necessity for stopping various engines for small repairs and adjustments, also the possibility of one or more engines breaking down.

(*d*) *Comparison speed* = 45 m.p.h. This figure has been arbitrarily assumed for the purpose of comparing high and low speed ships on a uniform basis. It has been purposely taken at a low figure in order to estimate the greatest distance it is reasonable to assume a rigid can fly under normal circumstances in still air, and also to give the longest number of hours a rigid can remain on patrol under normal conditions.

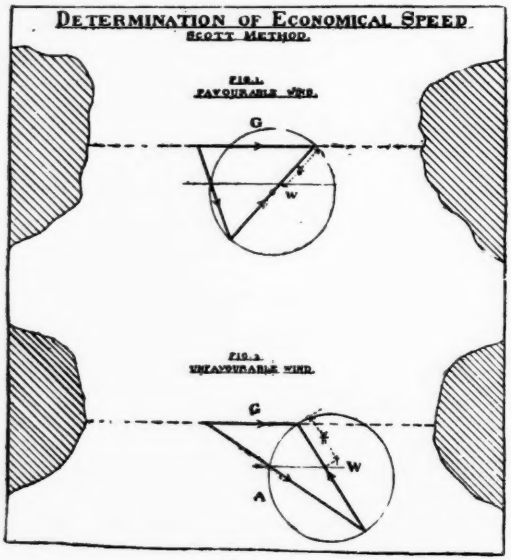

FIG. 4.

Keel.

The keel of a rigid has passed through several stages. As originally designed, it formed a kind of backbone to give strength to the hull. It was triangular in cross section and fitted outside the ship, hence the term "keel." This arrangement was soon found to be uneconomical. It increased the head resistance unnecessarily and made the ship less manœuvrable, and it was further found that the hull could be built equally strong and with less weight if the keel were done away with and the hull made uniformly stronger.

The keel was then almost entirely done away with, and a small internal keel or corridor was fitted inside the ship having little structural strength. This was found perfectly satisfactory from the point of view of the general strength of the hull, but in modern ships, with their high percentage of disposable lift, did not allow sufficient accommodation for petrol, water ballast and crew.

The keel as at present constructed is internal and of sufficient strength to carry the disposable weights. It should be regarded as a kind of weight distributor to which the various petrol tanks, water ballast bags, etc., are attached. Theoretically, with the present type of rigid, it would be more economical in weight if all fuel and water ballast were actually suspended from the various main

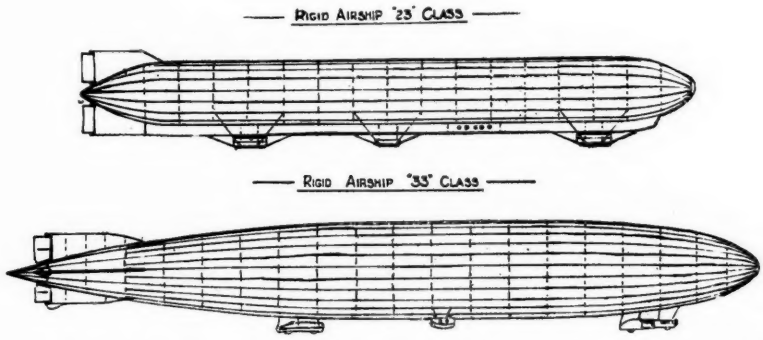

FIG. 1.—*Comparison between modern streamline and earlier parallel-sided rigids.*

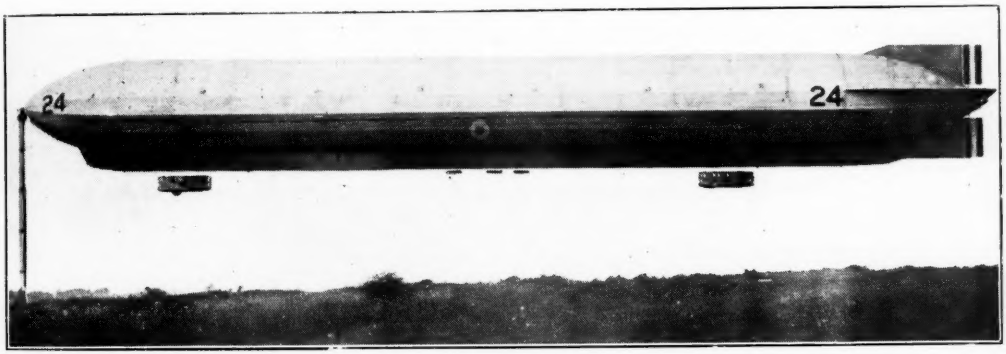

FIG. 2.—*R.34 riding to a mooring-mast.*

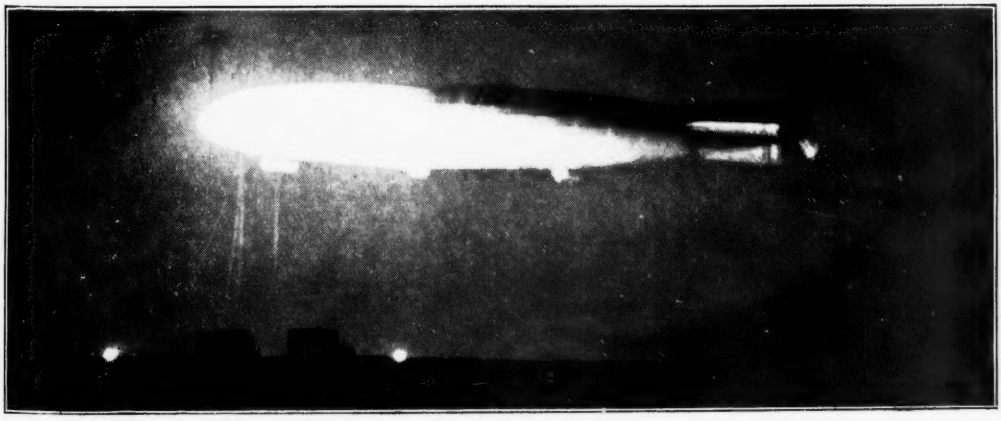

FIG. 3.—*R.34 moored out at night in America by the three-wire system.*

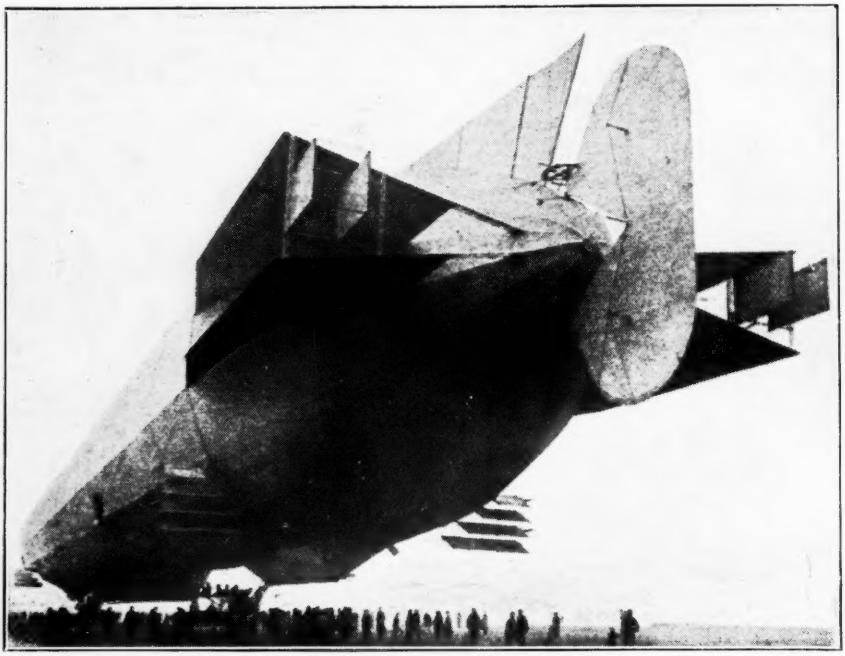

FIG. 6.—*Pre-war Zeppelin showing general arrangement of stabilising and control surfaces.*

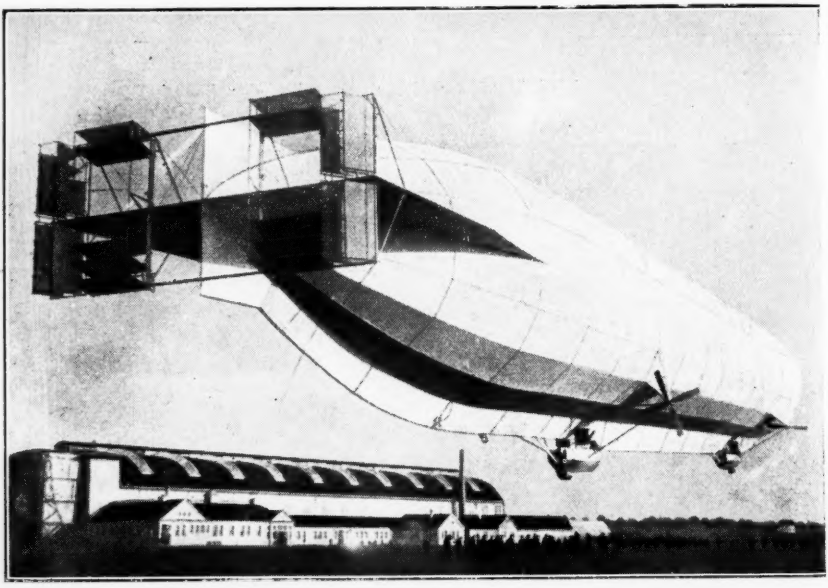

FIG. 7.—*Pre-war Zeppelin showing general arrangement of stabilising and control surfaces.*

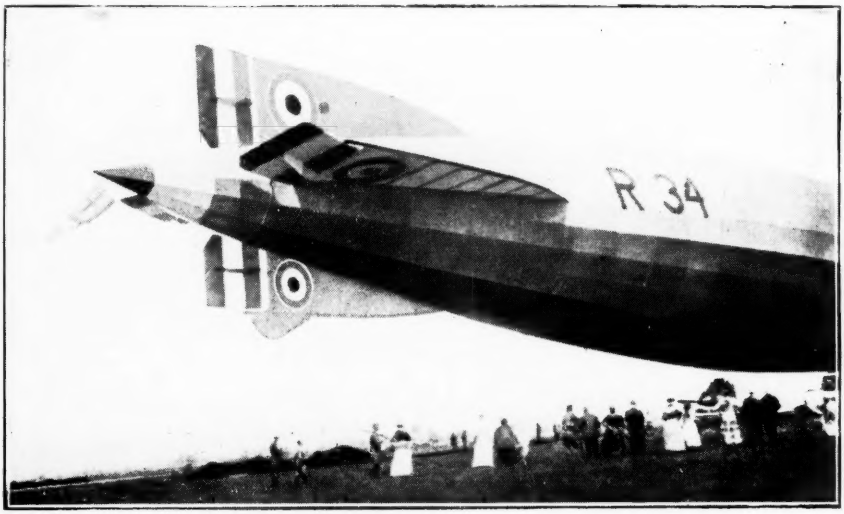

FIG. 8.—*R.34 showing modern simplified arrangement of fins and planes.*

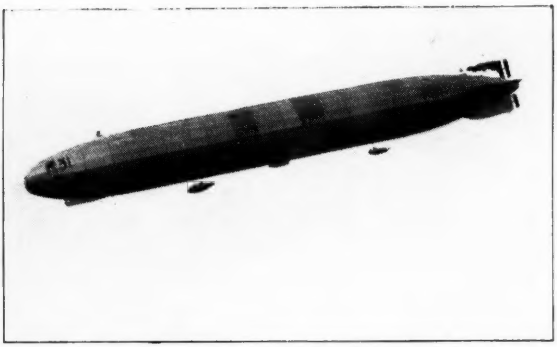

FIG. 9.—*R.31. Breaking up of top vertical fin during trial flight.*

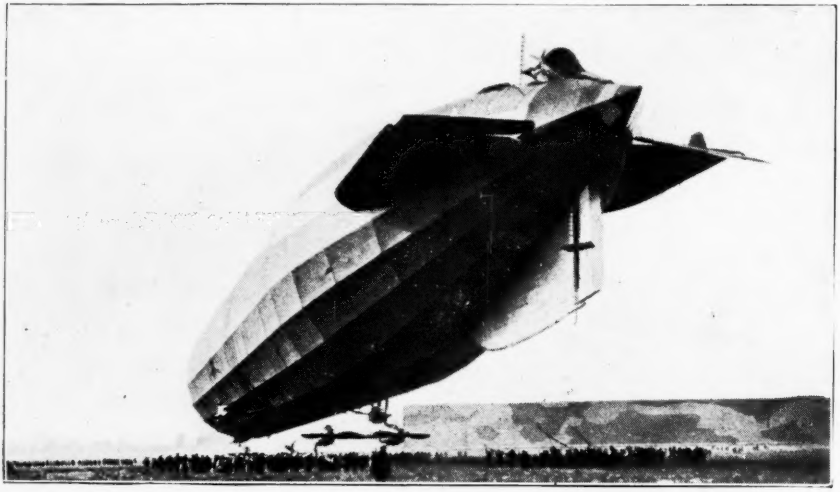

FIG. 10.—*R.31 landing. Top vertical fin and plane completely collapsed.*

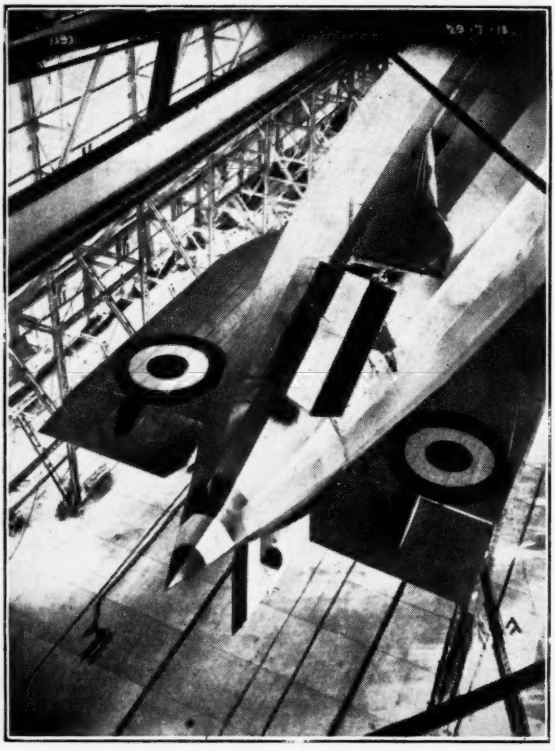

FIG. 11.—*R.31 in shed showing damage.*

NOTE.—Aside from illustrating faulty construction, the three photos of the collapse of the top vertical fin of R31 show most forcibly that what would have been a most serious accident to an aeroplane caused no attendant structural damage to the ship and no loss of life.

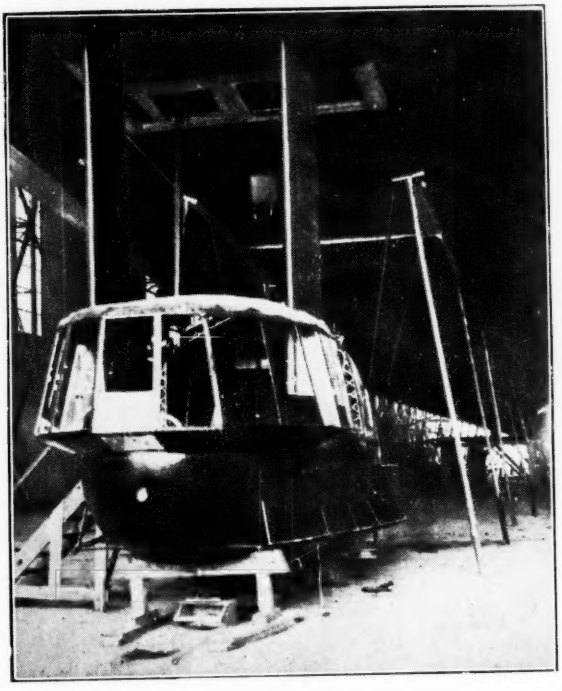

FIG. 14.—*Zeppelin type control car.*

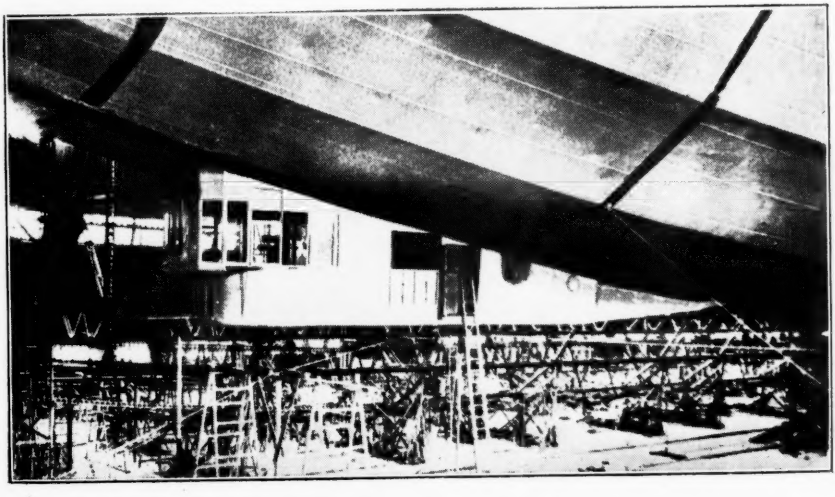

FIG. 15.—*British type control car.*

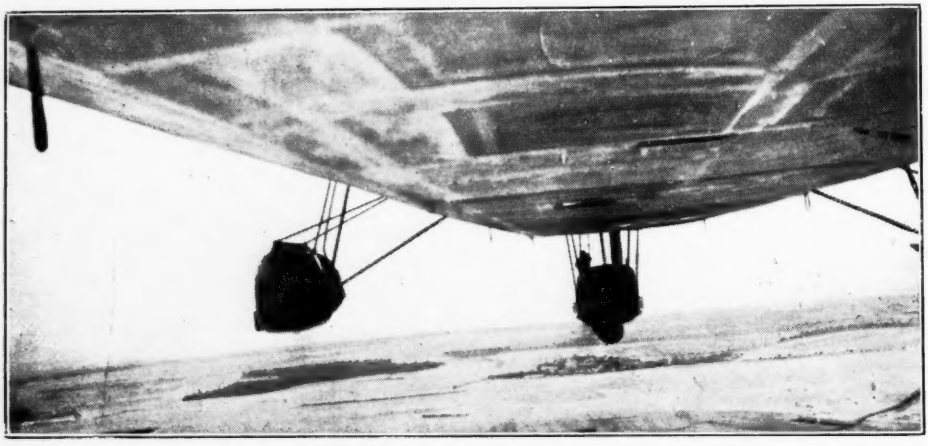

FIG. 16.—*Zeppelin type power car suspensions.*

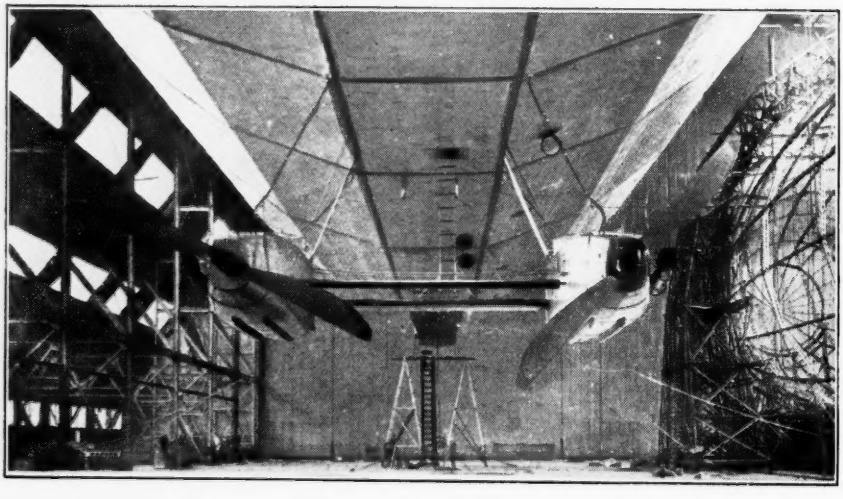

FIG. 17.—*British type power car suspensions.*

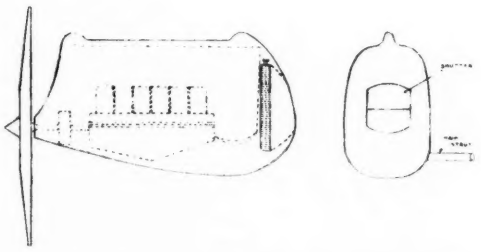

FIG. 18.—*Diagram of general arrangement of small German direct-drive power car showing radiator and variable air intake.*

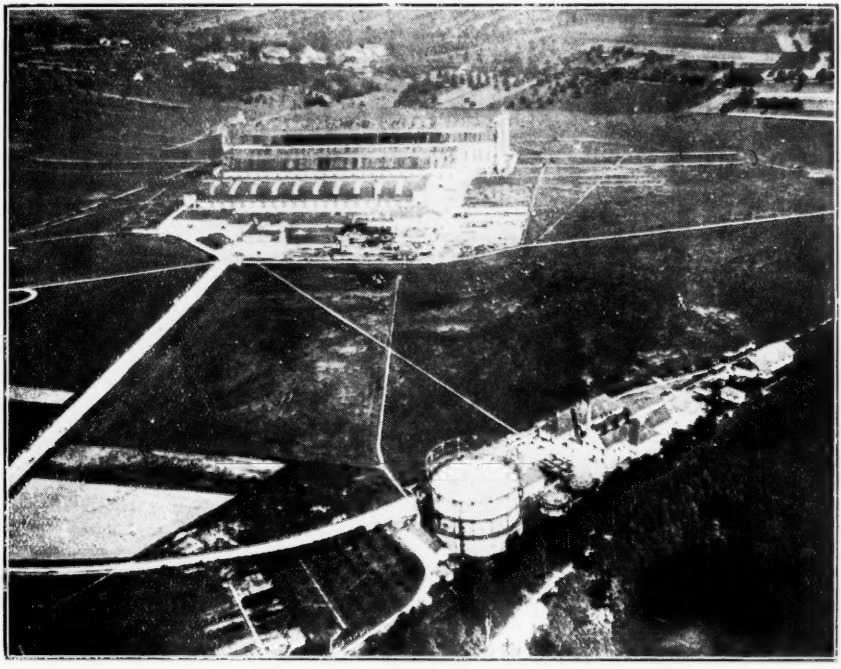

FIG. 19.—*German Zeppelin construction station at Friedrichshaven taken from Bodensee.*

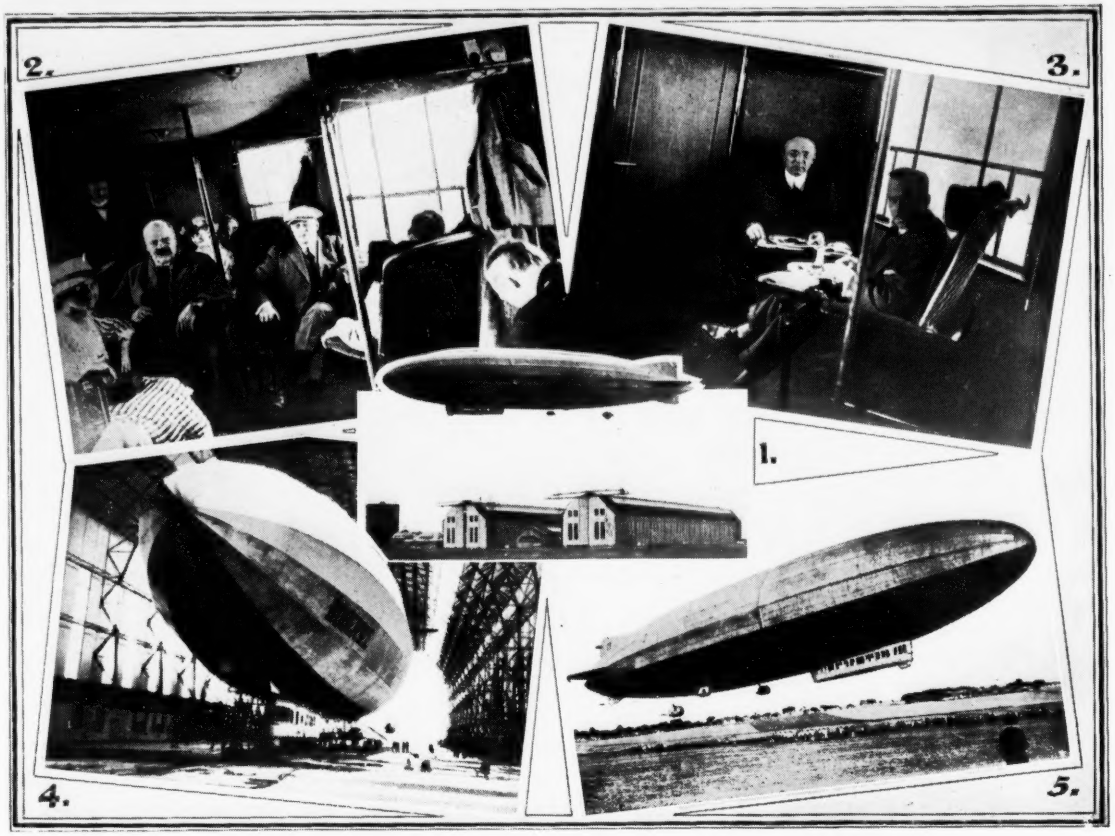

FIG. 20.—*The first German post-war commercial airship Bodensee.*

1. *Flying over sheds at Staaken, near Berlin.*
2. *Interior passenger car.*
3. *The same showing passengers at meals.*
4. *In the shed.*
5. *Side view showing passenger car.*

NOTE.—Although the Bodensee is of only about 750,000 cu. ft. capacity, she has a speed of 80 m.p.h. and carries 20—25 passengers with their hand luggage, also mails, a distance of 360 miles in from 4—6 hours. The regularity with which the Bodensee flies over this route (Berlin—Friedrichshaven) is remarkable. She has already carried out 60 flights in 63 days.

transverse frames, but in modern high efficiency rigids the actual bulk of water and petrol carried prevents this being done, and a certain amount has to be distributed between the various frames. It is, therefore, necessary to construct a keel in the form of a continuous girder of sufficient strength to support these weights.

Careful attention must be paid to the distribution of the various dischargeable weights fitted in the keel, and to their position as regards the centre of lift.

To a minor extent this is also necessary with certain of the non-dischargeable weights. For example, the sleeping quarters and the crew space should be so arranged that their centres of gravity are coincident, so that when the men leave their sleeping quarters and proceed to the crew space for food prior to going on duty, the trim of the ship should remain unchanged. The crew space should also be so arranged that its centre of gravity is roughly coincident with the watch on duty, so that the crew never change the trim of the ship. At the same time, in arranging the sleeping quarters, it is most desirable to choose positions as far away as possible from the power units, where the noise is excessive.

In the case of the dischargeable weights, the emergency (landing) water ballast should be fitted as near each end of the keel as possible, and should approximately balance about the centre of lift, so that the discharge of an emergency bag forward would give an up-angle corresponding in magnitude to the down-angle produced if an emergency bag aft had been discharged. The petrol should also balance about the centre of lift, so that the ship is equally in trim when completely filled with petrol ready for a long flight or when spent at the end of a long flight, or after rising to a great height. The normal water ballast should also be arranged to balance about the centre of lift. If, through some error in design, the ship is out of trim when spent, it should be noted that the amount of dischargeable weight necessary to correct this error in trim is to all intents and purposes dead weight, as it is impossible to use it without putting the ship out of trim.

Fins.

One of the most noticeable features of rigid construction in recent years is the reduction in fin area. This reduction in area is clearly seen in the illustrations of the 33 class compared with those of the 23 class.

The result to be aimed at is not to make the ship too stable, as was first considered desirable, otherwise, when she encounters disturbed air conditions and is thrown off her course either vertically or horizontally, it takes, owing to her over-stability, too long to bring her back again. This effect is more marked in the vertical plane, and it is much more difficult to maintain an over-stable ship flying at a constant height in disturbed conditions than one with less fin area. The point to be aimed at is to make the ship just stable enough, so that it does not too rapidly swing off its course, but can, at the same time, have its direction changed or corrected rapidly by the use of the movable planes.

Although the 33 class is of twice the capacity of the 23 class, the turning circle of the former is only about half as great as the latter, and in disturbed weather conditions the 33 class is by far the more controllable.

The old type of parallel-sided fin stayed to the ship by a large number of wires is gradually giving place to the new triangular streamline type fin. This type of fin does not appear to give quite the stabilising effect per unit area as the older type, but has the following important advantages which more than counterbalance its slightly lower efficiency. The triangular fin is for most of its length self-supporting. A great saving in head resistance is also achieved by the omission of all bracing wires except in way of the pintle bearings which, in both types, have naturally to be stayed. As far as weight is concerned, the triangular fins appear to have little advantage over the older type. The general cantilever arrangement,

Bodensee flies over this route (Berlin—Friedrichshaven) is remarkable. She has already carried out 60 flights in 63 days.

however, which enables the load to be distributed between three longitudinals instead of one as in the old scheme, is of great advantage, and further, by reducing the number of wires, the compression in the vertical members of the fin is considerably reduced.

Planes.

In the movable planes, just as in the fixed fins, considerable progress has been made.

Figs. 5 to 11 show the large number of small movable planes fitted to early rigids.

The next step in the development of movable planes was introduced by the Germans in their Schütte Lanz ships, and later copied by the Zeppelin Co., and has, up to last year, been considered the best arrangement.

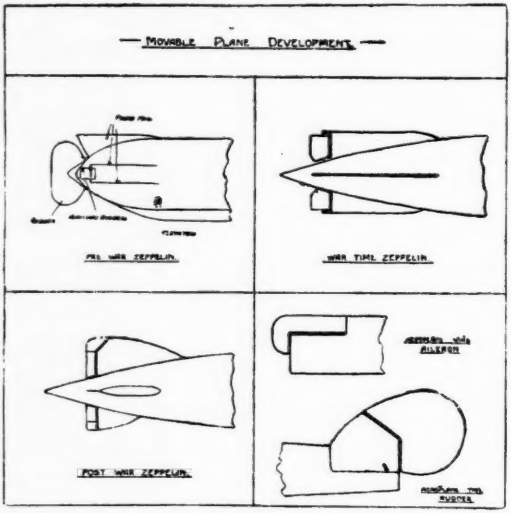

FIG. 5.

Recent experiments, however, have tended to show that the cruiser type of balanced plane, extensively used in aeroplane construction, is more efficient. The figure shows the development of airship planes from the early pre-war Zeppelin to the present "Bodensee," and indicates the similarity between the plane construction for this ship and for modern aeroplanes.

Dynamic Lift.

In order to obtain a clear appreciation of dynamic lift and its allied problems it is necessary to deal with a few preliminary questions connected with buoyancy. Phenomena which change the buoyancy of an airship may be grouped under three heads, and tend to make the ship either heavier or lighter than the surrounding air.

(1) *Fuel Consumption.*—This tends to produce positive buoyancy, and is capable of mathematical expression for any class of airship as a function of the speed at which the ship is flown.

(2) *Gaseous Superheating.*—By this diurnal buoyancy variation is produced if not masked by other effects. Maximum heaviness occurs about two

hours after sunset, and maximum lightness about noon, when the gas superheating is theoretically at a maximum.

(3) *Irregular Causes.*—Negative buoyancy is produced when an airship encounters snow, rain, or fog, when passing from sunshine into or under cloud, or when passing suddenly from cold air into warmer air. Conversely, positive buoyancy is produced when an airship passes from snow, rain, or fog, into sunshine, or when entering suddenly colder air.

It will, therefore, be seen that an airship is seldom in equilibrium with the surrounding air. To maintain a horizontal path the airship must fly at an angle up by the bow if heavy, down by the bow if light. This inclination of the axis of the ship in the vertical plane is caused at will by actuating the horizontal plane surfaces which, according to their inclination, tend to depress or raise the stern. If the ship is in equilibrium it tends to rise or fall at a rate $A \sin \theta$, where

A = the air speed.
θ = the angle of inclination of the axis of the hull to the horizontal.

If, however, the ship is light or heavy, the rate of rise or fall is no longer proportional to $A \sin \theta$. A point is finally reached where the rate of vertical rise (or fall) due to the positive or negative buoyancy of the ship, is equal to $A \sin \theta$. The ship then maintains a constant altitude, but flies at a constant inclination θ to the horizontal. $A \sin \theta$ can be increased by increasing either the angle of inclination or the speed. In practice, an angle θ of more than 8° is most undesirable, primarily because of the amount it slows down the speed due to the increased head resistance of forcing the streamlined hull unsymmetrically through the air.

The increase in size of ship also has an important bearing on dynamic lift. $A \sin \theta$ is independent of the size of ship, but the vertical rate of rise or fall due to a given percentage of positive or negative buoyancy is dependent on the surface area of the ship and, therefore, varies approximately as the (linear dimensions)^2. Hence, ships of similar form but of dissimilar size, flying at a constant speed and at the same percentage heavy or light, in order to fly at a constant altitude will have to take up an angle approximately proportional to the (linear dimensions)$^{\frac{2}{3}}$. In other words, under normal conditions, the low speed of the ship "A" will have to be increased with size to raise the value of $A \sin \theta$ proportionally to the (linear dimensions)$^{\frac{2}{3}}$,

When flying light or heavy an interesting phenomenon occurs, which is especially noticeable in modern streamline rigids fitted with small stabilising surfaces aft. As evening approaches and the superheating diminishes, the ship appears to become tail heavy at the same time as she becomes heavy, and conversely, in the morning as the gas superheats and the ship becomes light she appears to become at the same time nose heavy, so that in extreme cases of lightness the ship is flown with a constant down angle to maintain a constant altitude, but with the elevators hard up. If the ship becomes still lighter she gradually begins to lose height, and only rises when speed is reduced. The converse effect is experienced when the ship is heavy.

The explanation of this phenomenon appears to be that when a streamline form like R.33 is pushed unsymmetrically through the air, due to two forces acting on the ship at approximately right angles (namely, the force due to the thrust of the propellers acting parallel to the axis of the hull, and the vertical force due to the positive or negative buoyancy acting upwards or downwards, as the case may be), the airship tends to become unstable, the upsetting couple varying for small angles directly as the angle of pitch for any given speed. Naturally, the larger the stabilising surfaces the less marked will be this effect, and in practice it will be this form of eccentric instability which will determine the size of the horizontal fins and planes, as the stabilising area required for correcting this tendency is appreciably greater than is required to secure the

necessary degree of vertical controllability when flying in equilibrium through disturbed air. The amount of this couple is given by the formula :—

$$M = KV^2\rho\theta$$

where M = pitching moment.
K = a constant depending on the size and shape of the ship, including the area of its horizontal stabilising surfaces.
V = air speed of ship.
ρ = density of atmosphere.
θ = angle of pitch.

This dynamic effect can be minimised by altering the static trim of the ship; thus, when the ship is light and becomes dynamically nose heavy, petrol can be pumped aft to alter the static trim, and conversely, when the ship is heavy petrol can be pumped forward. This method of static trimming to correct dynamic trim must, however, be carried out with extreme caution, as after such trimming the ship is in reality either statically heavy and at the same time trimmed down by the bow, or statically light and at the same time trimmed up by the bow. This means that if, for any reason, the ship should be slowed down, she will if heavy dive rapidly and possibly crash into the sea, or if light rise rapidly, and, if flying with the gasbags nearly full, will inevitably rise well above her equilibrium height and become very heavy.

FABRIC.

Outer Cover.

One of the chief functions of an outer cover is to provide a smooth streamline form. It is, therefore, necessary that the fabric should be tightly stretched under all conditions of temperature and humidity. If, in flight, the outer cover sections sag in between the transverse frames owing to wind pressure, as much as three or four miles an hour are taken off the maximum speed of the ship owing to increased resistance.

Again, to obtain an outer cover with a long life, it is essential that it should be tightly stretched, so that it does not flap during flight when the ship is passing through disturbed air and the pressure distribution along the hull is changing rapidly. This tendency to flap can be decreased by providing adequate attachments to the diagonal hull wiring as well as to the girders, also by using a stiff dope which tends to prevent the formation of wave motion in the fabric. The great point to be realised in outer covers is that when dry the dope must absolutely control the fabric and not the fabric the dope. When wet the fabric should contract and assist the dope. A fabric should, therefore, be chosen which contracts strongly when wet, otherwise, under varying conditions of temperature and humidity, the outer cover alternately tautens or slacks off with disastrous results. For short flights this would be only a matter of inconvenience and high maintenance charges due to the rapidity with which the fabric would wear out, as after each flight the dope would regain control and tauten up the fabric after the ship had returned to her shed; but for long distance flights it is a matter of prime importance that the outer cover should be most reliable. All kinds of weather conditions may be experienced, and if the outer cover failed during such a flight the ship might easily be completely wrecked.

Various dopes have been tried. Latterly the base of all outer cover dopes is some form of cellulose acetate, although aside from its inflammability nitro cellulose appears to possess many advantages over cellulose acetate. The type of cellulose acetate used appears to be of great importance. In general, it would appear that the more soluble the cellulose acetate the less tough will be the resulting dope film.

Owing to the constant vibration of the fabric during flight, and the varying weather conditions met with, it is necessary that the dope should possess great

adhesion to the outer cover. With certain dopes this can, however, be carried to too great an extent. If, for example, the fabric is thoroughly saturated in certain dopes by passing the fabric first through a vacuum and then through the dope baths under pressure, the fabric tends to tear much more readily. The dope should, therefore, be so applied that it enters thoroughly into the texture of the fabric but does not actually completely fill all the interstices in the actual yarn.

The inner surface of the outer covers has generally been treated with a light coat of paraffin wax in the order of 2 g/m², as it was thought to prevent the absorption of moisture by the fabric on its inner side.

The dope requirements are manifold. It must be water repellent, and must also be as insoluble as possible, otherwise water is absorbed and the dope speedily loses control of the fabric, and, in extreme cases, actually washes off. For this reason it is generally considered desirable to apply one or more coats of varnish on top of the dope to increase the water repellent qualities of the dope. With badly doped outer covers ships of only 1,000,000 cu. ft. capacity (half the capacity of R.34) have absorbed as much as 3 tons of water during a heavy shower.

The outer cover must also reflect the heat rays to prevent superheating, and the ultra-violet rays to prevent deterioration in the fabric of the gasbag. It should be pointed out in this connection that the arrangement in rigids of two distinct layers of fabric each specially prepared for its special function, namely, the outer cover fabric and the gasbags separated by an air space of some 6 inches to 1ft., allows for far better results being obtained than is possible in non-rigids, or semi-rigids, where both functions have to be combined in a single fabric.

Superheating is of very great importance. During the summer months 20° F. of superheating is frequently experienced with the present outer covers. This means, for a ship of 2,000,000 c.f. capacity, an increase in buoyancy of about 2 tons when no gas is expelled, or a corresponding loss of gas should the gasbags be full. The best methods of preventing superheating appear to be:—

(1) To reflect as many of the heat rays as possible by mixing aluminium powder with the dope or varnish. It is necessary that the aluminium should be very evenly applied and the outer cover should be extremely glossy. For this reason there is a distinct advantage in applying a little aluminium with each coat of dope and not adding it solely to the last coat. It should be noted, however, that the admixture of aluminium powder to the dope lessens the adhesion of the dope films although it increases its water repellent qualities. It would therefore appear more advantageous to concentrate all the aluminium in the last one or two coats. The effect of varnish is of advantage as it tends to produce a more glossy reflecting surface, and thus increases the reflecting qualities of the outer cover. Varnish also increases the water repellent qualities of the outer cover and protects the dope from the softening action of rain.

(2) It is of importance that all heat which is not actually reflected by the outer cover should be absorbed by it, and not allowed to pass through to the gasbag fabric where it must inevitably heat the gas. It is, therefore, theoretically desirable that some form of dark coloured dye should be added to absorb this heat, or that the first one or two coats should be mixed with pigment such as yellow ochre or red oxide of iron. It is probably not desirable to apply the dye actually to the fabric itself, as all dyes so far experimented with tend to weaken the strength of the fabric, and if dye is used at all it will probably be mixed with the first coat or two of dope, the aluminium being added to the final coats. If the aluminium is applied as a sufficiently even and dense coat, however, it does away to a great extent with the necessity of adding dye to the early coats.

(3) A certain amount of heat will not be reflected and will pass through the outer cover. As much of this as possible should be prevented from being absorbed by the gasbags by arranging a uniform and brisk system of ventilation between the outer cover and the gasbags. The amount of heat that passes through the outer cover will, to some extent, depend on the speed with which the ship is passing through the air. Naturally, the faster the ship travels the greater is the cooling effect of the air rushing past the outside of the outer cover.

Superheating causes even more inconvenience when the ship is moored out than in flight. It is necessary that any ventilation system provided to carry off the heat from the outer cover before it warms the 6in. or so of air between the outer cover and the gasbag should be so arranged that it is approximately as brisk when the ship is stationary at a mooring mast as when flying through the air at, say, 50 or 60 knots. For this reason it seems probable that the best arrangement will be to provide air intake apertures along the under portion of the hull, and air outlets at the top of the ship with small hoods opening aft and protruding possibly three or four inches above the top of the ship. It has been suggested that, owing to the large number of excrescences along the top of the ship caused by these hoods and by the hoods for the manœuvring and automatic gas valves, it might be an appreciable saving in resistance to construct a small ridge right along the top of the ship which would contain all the various outlets, so arranged that there would be a slight suction due to passage through the air and at the same time prevent rain entering the ship.

VERTICAL SYSTEM OF VENTILATION

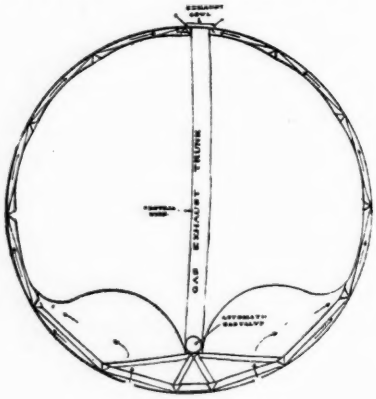

FIG. 12.

A great advantage of any vertical system of ventilation as outlined above is that when the ship is stationary at a mooring mast during sunny weather, the heat not reflected by the outer cover will be absorbed and will raise the temperature of the outer cover, which will in turn warm the layer of air between it and the gasbags. This layer of warm air will cause a differential pressure proportional to the diameter of the ship, and a steady current of air should, therefore, pass through the space between the outer cover and the gasbag, the cold air entering at the intake ports in the lower surface of the ship, the hot air passing out through the exhaust ports at the top. As the temperature increases the rate

of ventilation will naturally increase, and the cooling effect will, therefore, be more or less automatic and will increase as the superheating becomes more pronounced.

The early outer covers used in England were made of linen. This fabric was used on account of its great tensile strength in relation to its weight. The balance of opinion now, however, is in favour of mercerised cotton outer covers. To assist the dope in wet weather it is, however, of importance that a fabric should be chosen which contracts strongly when wet, and in this respect mercerised cotton appears to be superior to ordinary cotton or to linen.

In early ships the outer covers were completely doped at the fabric works before being attached to the ship. This arrangement is most undesirable owing to the damage to the dope film during transit from the fabric works to the airship construction station, and to subsequent damage during attachment to the ship. The difficulty of obtaining the correct tension is also considerable.

The present practice is to apply mechanically one to three coats to the fabric, which is then made up into panels of various sizes ready for lacing. The outer cover is then attached to the ship and one or more final coats of dope or solvent are then applied *in situ* to produce the necessary tension in the outer cover, and a subsequent coat of varnish to give a more water repellent and glossy surface may also be applied *in situ*.

The two methods of applying dope *in situ* are by brush or by compressed air spraying machines. The second method produces much more even doping and in this respect is much to be preferred. Unfortunately many dopes, cellulose acetate dope in particular, cannot be applied by this method, especially if they contain a large admixture of aluminium.

A point to be considered is the admission of light to the corridor, which will be almost in complete darkness if a dense aluminium surface is applied to the outer cover. As most of the superheating is caused by the sun's rays striking the upper surface of the outer cover, probably the best method is to provide a strip of outer cover running along the bottom of the hull doped with transparent dope. This portion should anyway be varnished to increase its water repellent qualities.

Specially thick panels are fitted in way of each propeller. This is necessary, due to the disturbed nature of the slip stream, and further, in cold weather, it is possible to damage seriously the thin outer cover, owing to small fragments of ice being driven against the outer cover by the propellers.

Gasbags.

The main problem in rigid gasbags is to obtain a light and strong fabric which is, at the same time, sufficiently gastight. The greatest tension is naturally applied to the upper part of the gasbag owing to the differential pressure between the gas and air. In the case of future ships of larger diameter, economy can probably be effected by constructing a composite bag with thicker fabric in its upper portion. The fabrics at present in use are either fine cotton of from 50 to 85 gms. in weight, or fine silk approximately 30 gms. in weight.

Gasbags in this country are usually constructed of single ply cotton and are covered on their inner surface with a single layer of goldbeater skin attached to the fabric with rubber solution, except at the extreme top where two layers are used. The skin is then covered with varnish to prevent absorption of moisture during damp weather. In the older ships of the 23 class as much as one ton loss in lift appears to have been sustained, due to absorption of water by the gasbags.

In Germany it is customary to use somewhat lighter gasbag fabric than in this country and two layers of goldbeater skin, and the goldbeater skin is attached to the fabric by a kind of glue. As far as can be seen the glue offers no advantage

over rubber, and is probably used owing to the extreme scarcity of rubber. In German gasbags the two layers of skins appear to be regarded as providing the requisite strength as well as the gastightness, and the main function of the outer layer of thin fabric (cotton or Japanese silk) is to protect the skins from abrasion.

Although the goldbeater skin forms an extremely light and efficient gas-container, it is, nevertheless, a most undesirable material. In the first place, the supply of skins is limited, as only one skin is obtained per animal. Some 600,000 skins are used per rigid of the 33 class to provide a single layer of skins. The cost of this is appreciable, as skins at present are worth about $1\frac{1}{2}$d. each, and the amount of labour employed in scrubbing, cleaning, and applying these skins to the fabric is excessive. In fact, the total cost of a complete set of skin-lined gasbags is at present not far short of £40,000.

Many attempts have been made to obtain a light gastight fabric by means of flexible dope, and experiments have reached such a stage that it can be assumed without undue optimism that it is only a matter of a short time before it will be

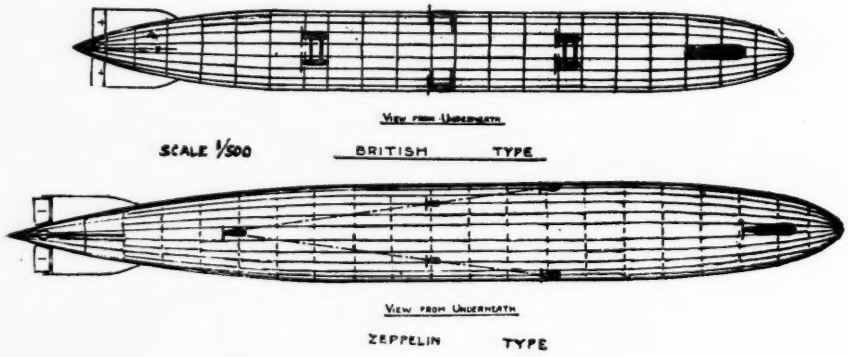

FIG. 13.—*General car arrangements.*

possible to use a light flexible dope applied to single ply cotton fabric. The total weights of a typical British gasbag fabric are as follows:—

Single ply goldbeater skin	18—20	gms./m².
Rubber adhesive	40—45	,,
Rubber proofing	20	,,
Varnish	8—10	,,
Cotton	75	,,
Total	161—170	gms./m².

There is every possibility that it will be practical to use even lighter fabric of, say, 50 gms./m² for Service rigids where the last ounce of efficiency is of the utmost importance. Owing to the risk of damaging this fabric and the extra cost of obtaining such very finely woven cotton, it is probable that, for commercial ships, heavier fabric will be used.

A curious feature in gasbags is that they maintain their gas-containing properties for a reasonable time and then suddenly become porous. In nearly every case the gasbag has to be removed within a fortnight of the beginning of this sudden collapse in its gastight qualities. Generally speaking, the gasbags last about two years.

The automatic valves have now reached about the limit in size, having regard to their very light construction.

In rigids larger than 2,000,000 cu. ft. capacity it is probably best to fit two automatic valves instead of one, situated at the bottom of the butt end of each gasbag.

Too great stress cannot be laid on the extreme importance of gasbags blowing off at a more or less uniform pressure. Naturally, the pressure at which the gas valves blow off is higher at the ends of ship than midships.

AUTOMATIC GAS VALVE SETTINGS.

Gasbag No.	No. of Valves.	Diameter of Valve Discs in m/m.	Valve setting in m/m. of water pressure.
XVIII.	1	Small Valve 545	16
XVII.	1	,, ,, 545	16
XVI.	1	,, ,, 545	13
XV.	1	,, ,, 545	13
XIV.	1	,, ,, 545	10
XIII.	1	Large ,, 800	10
XII.	1	,, ,, 800	9
XI.	1	,, ,, 800	9
X.	1	,, ,, 800	9
IX.	1	,, ,, 800	9
VIII.	1	,, ,, 800	9
VII.	1	,, ,, 800	9
VI.	1	,, ,, 800	9
V.	1	,, ,, 800	9
IV.	1	,, ,, 800	9·5
III.	1	,, ,, 800	9·5
II.	1	Small ,, 545	13
I.	1	,, ,, 545	13

CARS.

General Car Arrangement.

In rigid airships it is obviously undesirable to concentrate too much weight at any one point. For this reason it is necessary to split up the total amount of power required into several distinct propelling units, bearing always in mind, however, modifying factors such as the h.p. of available prime movers, propeller efficiency, maximum weight and thrust which can be concentrated conveniently at any one point, and the number of units required to give the requisite reliability.

Several systems of car arrangement have been in vogue from time to time.

The Zeppelin Company's arrangement is to fit one large composite centre line car forward, containing in its front end the control and observation car. A car containing a power unit is fitted immediately behind the control car, the two cars being separated by a space of about one inch to prevent much of the noise and vibration passing from the power car into the control car. The wireless cabin is situated in the after part of the control car. A second centre line car is fitted well aft, containing a power unit. Between these two cars are fitted one or more pairs of small wing cars arranged at varying distances from the centre line of the ship, to prevent slip-stream interference. The forward and after cars are also fitted with buffer bags and handrails, and are used as the two points of contact for handling purposes on the landing ground. Figs. 13 and 14 of the car disposition of the German L.70 class illustrate this type of general arrangement.

The British system, except where German practice has been copied, provides for one small centre line control car fitted well forward. In some cases it can hardly be regarded as a car in the strict sense of the word, but rather as an excrescence built out from the internal keel of the ship where the bow begins to

rise. This car only contains the control gear and wireless cabinet. Aft of this, two or more pairs of wing cars are fitted at varying distances from the centre line of the ship to prevent the slipstreams of the forward cars blowing on to the after units, thus increasing head resistance. On the landing ground, the ship would generally be supported at its forward end by the control car and at the after end by a pair of wing cars. In certain cases, however, the control car is fitted so far forward that it is always well off the ground, in which case the bow of the ship is supported on the landing ground by the forward pair of wing cars.

The present tendency in England is to regard this system as the more efficient. In the first place, the overall height of the ship can be appreciably reduced. In the Zeppelin type the overall height must be about 13ft. more than the maximum diameter. In the British arrangement, it is possible to bring the overall height down almost indefinitely, so that in an extreme case it would be no greater than the maximum diameter of the hull. In practice, however, it is desirable to fit the cars in such positions that the hull is always kept at some five or six feet above the ground to allow for inequalities in the surface of the landing ground which might otherwise damage the hull structure while handling the ship on the ground. The reduction, however, of some 7ft. in overall height compared with the Zeppelin system is, in practice, of considerable importance, due to the small size of existing shed accommodation. A third advantage is that the wing power cars, probably owing to their small size, are more efficient than the larger centre line cars. This is especially the case with the large forward centre line car which, as has already been stated, contains, besides the power car, a wireless cabinet and control car, and the resulting composite car is of necessity of such size that it somewhat blankets the propeller. In the case of the R.33 class, the lack of efficiency in the after car is probably to some extent due to the fact that it contains two engines and is of bad streamline form.

In the British system each car is used for its special function, and there is no loss of efficiency due to making a compromise. In this way each power car can be exactly the same and only the slinging arrangements need be slightly varied.

It seems probable that for many years to come the machinery installation will be the most unreliable part of the ship during flight, and will, besides, require the most frequent overhauls and renewals. It is obviously equally important that both service and commercial rigids should be laid up for a minimum number of days per year and not for long periods as heretofore while their machinery is overhauled. Provision should, therefore, be rapidly developed whereby the power cars, as complete units, can be rapidly changed. No reason is seen, in the future, why such units cannot be so simplified that it will be possible, without actually taking the ship into the shed, to change one or more of the complete units. Besides providing standard power units, the separate parts such as the engine, transmission gear, etc., should be designed to be rapidly replaceable by new standard parts. Too great emphasis cannot be laid on the importance of standard power units.

Car Suspensions.

Two main types of car suspensions are also in force :—

1. The Zeppelin type.
2. The British type.

The Zeppelin Company attach their cars by means of a combination of struts and wires. The struts take the compressional forces due to the thrust of the propeller and maintain the car at the correct distance from the centre line of the ship. The wires bear all tensional strains and, broadly speaking, take the weight of the car.

The British arrangement allows for a minimum of struts which are only fitted transversely to maintain the car at a given distance from the centre line, the thrust of the propeller being taken by a wire which is led out through the centre of the propeller aft.

Although the British system is the less complicated and provides a more elastic form of suspension, which transmits less vibration to the hull of the ship, much instructed opinion appears to favour the Zeppelin arrangement on account of its greater safety and reliability.

The British cars, on account of the absence of vertical struts, are called " floating " cars. In the case of a heavy landing floating cars are an advantage, because, except in extreme cases, the cars alone are damaged and the vertical struts are not driven upwards into the hull of the ship, breaking the main framework at the upper point of attachment.

The Zeppelin arrangement attempts to get over this by carefully adjusting the strength of the struts so that, when a heavy landing is made, the struts break before the hull structure of the ship is damaged.

Looking into the future, however, it does not seem necessary to allow for bad landings. Few have been made recently by British pilots, and the few German pilots of experience appear to make consistently good landings with no fear of damage. A certain number of heavy landings were made throughout the war in Germany, but if the matter is looked into these heavy landings can be traced to war emergencies or to the inexperienced captains of ships. In Germany, partly owing to its proximity to England, rigids were not used in a legitimate way, and their bombing raids produced such a high percentage of mortality in their flying crews that much difficulty was experienced in maintaining highly trained and experienced flying personnel.

The question of car suspensions in general is one of considerable difficulty and complexity. The arrangement has naturally to be simple and of low head resistance. It has to provide for the ship taking up a considerable angle of pitch (some 35 to 45 degrees up or down). With the present large geared-down pusher propeller, it is, besides, a matter of some difficulty to arrange a simple and reliable method of taking the thrust. In the most recent power units this has to some extent been overcome by the increase in speed of rigids and great reduction in size of the power egg. This allows much smaller direct-drive propellers to be fitted without undue blanketing. If the car is designed to have considerable overall height aft it is possible to take the thrust by means of a wire attached to the after end of the girder which runs along the top of the car. This wire, which just clears the propeller, is led aft and attached to the hull.

At first sight this type of car would appear to be of somewhat high head resistance, because, although well streamlined in plan, it is badly streamlined in elevation. It appears, however, that when fitting a small appendage to a large streamline body, the inner side of the appendage should not be streamlined, but should lie parallel to the large streamlined body to which it is attached. This, it is seen, is complied with in the car shown in Fig. 18, which is streamlined in plan and underneath, but the top is roughly parallel to the underside of the ship, and consequently does not cause as much disturbance in passing through the air as would be the case if it had been perfectly streamlined.

Power Units.

Naturally, the three main points to be achieved in designing the power units for a rigid airship are :—

(1) Reliability.
(2) Low petrol consumption per unit of thrust-horse-power.
(3) Low head resistance.

Assuming that heavy duty reliable engines are available of various horse-powers, several points arise. In the first place, the greater the number of engines the greater the reliability, and, generally speaking, the greater the efficiency of the propellers, owing to the smaller h.p. of each unit. At the same time, the head resistance and weight of the installation will be materially increased, also, each additional power unit requires at least two engineers, one on duty and one off, complete with their food, parachutes, sleeping accommodation, etc. It is seen, therefore, that there are important reasons for not fitting more power units than are absolutely necessary from the point of view of :—

(*a*) Not concentrating too much weight at one point.
(*b*) Not increasing the h.p. of each unit to such an extent that the propeller becomes too inefficient.
(*c*) Maintaining the necessary degree of reliability, having regard to the probable reliability of each power unit as a whole.

Where the h.p. required is not too great, a vertical engine is most suitable and easy to instal. Two clutches are at present required, one a dog clutch, the other a multiple disc. A reverse gear should be fitted to at least one-half of the power units for assisting in landing and mooring.

Generally speaking, greater efficiency is obtained with a large geared-down propeller. On the other hand, no very satisfactory form of gearing is available. Epicyclic gearing, although occupying little room and weighing much less than the ordinary spur gear, has not so far proved to be sufficiently reliable, and the ordinary tooth gearing takes up a good deal of room and is very heavy, the non-reversing gear and transmission in R.33 weighing as much as 54 per cent. of the weight of the engine, and for the reversing units 66 per cent.

In practice, with a fast rigid of some 2,000,000 cu. ft. capacity, it is probably more efficient to fit very small streamline power units, each unit developing from 250 to 300 h.p. and actuating a direct-drive 2-bladed propeller, except in those cars where it is necessary to fit a reverse. A brake should be fitted to the transmission shaft between the propeller and the clutch, so that the propeller can be allowed to rotate when the engine is not running, thus minimising head resistance, but so fitted that the propeller can at will be brought to rest for landing purposes, etc., by applying the brake.

Pusher power units are more suitable than tractor units and are always fitted. They simplify the slinging, and are generally more convenient and efficient.

The best position in which to fit the radiator is doubtful, and several views are held. The general requirements are as follows :—

1. The radiator must be so fitted that it can at will be thoroughly protected from the outer air during cold weather flights when the engine is not required to be run or when under repair, to prevent rapid freezing of the radiator water.
2. To give maximum cooling efficiency with minimum head resistance.
3. To be fitted in such a position in those units provided with a reversing propeller that, when running in the reverse direction, the radiator still provides efficient cooling.
4. Ease of inspection during flight.
5. Ease of refilling with water during flight.
6. Means of varying the area of cooling surface, or conversely, the draught, so that an approximately constant temperature can be maintained under varying conditions of air speed and air temperature.

Engines.

The tendency during the war has been to produce a number of highly efficient aircraft engines from the point of view of weight per B.H.P. In designing these

engines, however, reliability over long periods and low fuel consumption have been in nearly all cases a secondary consideration.

The main requirements for a rigid airship engine are :—

1. Reliability.
2. Fuel economy.
3. Ability to develop continuously a high percentage of its maximum B.H.P., *i.e.*, to run continuously at about nine-tenths full power.
4. Low maximum revolutions, in the order of from 800 to 1,400 r.p.m.
5. Simplicity and ease of carrying out overhauls in the air.
6. Ability to run for long periods without overhaul.

An airship engine possessing such qualities will effect a considerable gain in efficiency over present aircraft engines for long flights, even if it is necessary to allow as much weight as 6lbs. per B.H.P. It would appear, in this connection, that the engine requirements of large seaplanes and large bombing aeroplanes are very similar to the above; and it is, therefore, essential, if this country is to regain supremacy in the air, that the aircraft designing resources of this country should be directed towards the production of heavy duty aircraft engines as well as the present high performance type. Low fuel consumption is of extraordinary importance in rigid airships, where long flights of 100 hours and upwards are possible. A saving in fuel consumption of .05lbs. per B.H.P. hour means that for every 100 hours of flying no loss in endurance would result if the weight of the engine were increased by 5lbs. per B.H.P. A great fault in many aircraft engines fitted to airships during the war is that although reasonably economical in fuel consumption at full power, their economy falls off rapidly when run at the necessary reduction in power to produce reasonable reliability.

A vertical engine is in general more suitable than the "V" type of engine, and should be adopted in all cases where the h.p. required per cylinder is not too great, as it allows for the construction of a narrower power unit of appreciably lower head resistance. A vertical engine is, besides, more accessible and easier to repair during flight than the "V" engine.

The most suitable h.p. for airship engines is a matter for careful consideration. As previously indicated, this question is rather a matter for compromise, having regard to the amount of weight desirable to concentrate at a single point, and the number of units required for the ship to obtain the necessary degree of reliability. As a modifying factor, however, it should be noted that the efficiency of a direct drive propeller at present falls off greatly in engines of over 400 h.p., and thus the petrol consumption per unit thrust tends to increase with more powerful engines. On the other hand, with more powerful engines it is possible to construct power units of lower head resistance per B.H.P., and the weight per B.H.P. of the whole unit also tends to decrease with increase in power.

The question of fitting steam engines to rigid airships in place of the present internal combustion engines, is a matter of some interest. The steam engine is extraordinarily attractive but for one drawback, namely its heavy fuel and water consumption per B.H.P. hour. Till this can be got over the steam engine is completely debarred. The actual weight of the installation, however, does not appear excessive. The petrol engine suffers greatly from loss of h.p. with height, as unless fitted with forced induction the h.p. tends to decrease as the density of the air. In the case of the steam engine no such loss of h.p. with height is experienced, and as an airship requires to fly at various heights owing to meteorological conditions, etc., this quality would be of considerable advantage. The very great reliability, ease of reversing, flexibility, and silence need hardly be emphasised.

The question of the most suitable fuel is one of very great importance. Owing to the method of storage, the fuel must not be viscous and likely to clog the pipes bringing it from the internal keel to the power units. A low freezing point

is also essential for flying at great heights or in winter weather, and this rules out such spirits as benzol.

To the uninstructed mind, danger of fire in airships is generally thought to be due to the presence of hydrogen, and for this reason one frequently sees in the Press articles dealing with the desirability of adopting helium at all costs. A far more important question appears, however, to be completely ignored, namely the danger of fire due to fuel ignition. If the fate of an airship carrying from 20 to 50 tons of briskly burning petrol, whether inflated with hydrogen or helium, is contemplated, it will be readily realised that the advantages in the use of helium are not so obvious as would at first sight appear. If, further, the number of aeroplanes shot down in flames during the war, or which caught fire by themselves due to some failure in the petrol system or engine, is considered, it will be seen what an extraordinarily dangerous fuel petrol is.

Since the outbreak of war, British airships have patrolled over 2,000,000 miles. During this period of over five years there have been in all only eight cases of a British airship being destroyed by fire, five of these during flight and three on the ground. Of these eight cases, six can be definitely traced in the first instance either to actual petrol fire or to some cause originating in the engine. Of the remaining two cases, one airship was shot down in flames by a hostile seaplane, the inference being that the hydrogen was ignited by incendiary bullets; in the second, an abnormal, case an airship broke loose on the landing ground and finally drifted on to some telegraph wires which apparently ignited the hydrogen. It will, therefore, be seen that in the great majority of cases the fires are attributable to other causes than hydrogen.

The heaviness of petrol vapour opposed to hydrogen is an additional cause of danger, as it tends to hang about the bottoms of the enclosed power cars and in the keel where the petrol is stored, unless very special precautions are taken, whereas hydrogen, owing to its lightness, tends to rise rapidly. The comparative immunity of airships from fire compared to H/A craft, excluding enemy action, is probably attributable to the fact that saving in weight at the expense of reliability is not considered of such prime importance in the machinery installation of airships, and more rugged fittings have been used and more extensive safety precautions employed. The greater accessibility to the actual engine in airships also tends to minimise this risk. Nevertheless, it is clearly most necessary that every effort should be made to abandon petrol as a fuel for airship engines, and substitute a less volatile fuel such as paraffin.

Conclusion.

I had hoped, in this Paper, after dealing with the various parts of a rigid, to discuss problems such as mooring, water recovery, and passenger accommodation, which all have an important bearing on structure and performance. This has proved to be impossible in the time allowed.

In conclusion, let me give some of the salient achievements of British airships. First, they have collectively patrolled and convoyed for over 2,000,000 miles during the war. Secondly, during the ten months of 1918 prior to the Armistice the proportion of days upon which airships carried out their flights was 97 per cent. Since then the problem of mooring rigid airships to a mast has been solved, and it is now as easy for a rigid airship to fly to, fly away from, and ride to, a mooring mast as it is for a surface craft to moor to a buoy. The record of coastal airship No. 9 emphasises the reliability of the individual airship. Her life was two years 75 days, her time in the air 2,500 hours, giving a flying average of three hours six minutes per day for the whole life of the ship.

Thus the actual achievements of British airships during the last five years, both their reliable, useful, and regular patrol work, and their great range as illustrated in the Baltic and Transatlantic flights of R.34, show more strongly

than any words the very great future which lies in front of airships, especially when the improvement in performance which is automatically achieved merely by increase in size is realised. I hope, however, that this Paper has shown that the actual details of airship construction are still in their infancy, and that equally important improvement in performance, due to refinements in detail, can be predicted in the near future, if energetic airship research and experimental work be carried out.

Airship development is now being rapidly pushed forward in America, France, Italy and Germany. To this country airships are of even more importance, owing to the scattered nature of the British Empire and the undisputed supremacy of the airship for rapid long-distance transport. Great strides have been made during the war, even though Great Britain came late into the airship field; but she has now, by several years of unremitting effort, gained there a position second only to that of Germany.

DISCUSSION.

The CHAIRMAN said he was glad to welcome there Sir Alan Anderson, who was closely associated with the fortunes of the Orient Steamship Company. During the war he was at one time one of the Lords of the Admiralty in his capacity as Controller of the Navy, and during that time he was responsible for the construction of our airships and was extremely sympathetic in helping the Airship Service during its teething troubles, and the Airship Service consequently owed Sir Alan a genuine debt of gratitude. He had proved himself a great believer in the future of the commercial airship, and he (the Chairman) was hoping they might prevail upon him to give some of his views on airships.

Sir ALAN ANDERSON said it was embarrassing for a non-technical person to be called upon to open a discussion before a technical audience, but perhaps he might be regarded as technical in the sense of a potential user of these craft. Apart from the sporting interest which they all took in this new element, he was interested in seeing whether one could apply airships to commercial purposes. The difficulties were great but he did not think them insuperable. Last week there were some paragraphs on the subject, and one paper represented General Maitland and himself as having been responsible for them. They were prophecies of things which might occur in the future, but not, he thought, in the near future. He was not responsible for the paragraphs, and he did not think General Maitland was. He thought these ships should be thoroughly tried out now, and that a definite conclusion should be arrived at as to whether there was a commercial possibility for them at the moment. That first stage would be experimental, and the Government would have to take a large share, but when that stage was over the public, who were always keen to be in a new thing of that sort, would come in and airships would be tried out on a commercial scale. He wished to refer particularly to the part of the Paper in which speed was dealt with. He was told by an expert in submarine work that the problems under the water were almost identical with those of air navigation. The problems of sea navigation, at any rate, were very similar. There was the same need to judge between the desire to hurry, to carry weight and to save first cost. It was different, however, in a few particulars, for instance, ocean steamships had now enough power to steam off a lee shore, to avoid being driven ashore in a gale, but he supposed when an airship commander found the Himalayas under the lee he got anxious when a gale came. A big speed and big power were wanted to overcome the drift, and it would be some time before the airship would have that reserve of power which the common tramp possessed to-day on the ocean. Another point that struck him was this, and it was in favour of the airship. When one wanted more speed

with a surface ship, one must have immense size and ships like the "Lusitania" and "Mauretania" were made of that immense size to carry the coal required for their speed—for no other purpose. The hull of those ships was filled with engines and coal and the superstructure provided luxurious space for a large number of passengers. Unless enough people wanted to travel to fill this great passenger space the ships could not have an economical load. That meant that a very fast steamship service to be commercial must link up two great centres of population, like New York and London or New York and Liverpool. In his business they were linking up England and Australia, and Mr. Hughes, when talking to them about new ships for the mail service, said the proposed speed was not nearly fast enough. He wanted 23 or 24 knots, the same as the Atlantic liners. But it would not pay, as there were not enough people wanting to go to Australia to justify the provision of immense ships which alone could go that distance at that speed. In the air it was a different problem. A small number of passengers—50 or so—would be carried at three to five times the speed of the fastest steamship and the airship service would link up comparatively small numbers of busy men, who would pay a big price for getting about rapidly. He thought the technical men had got over the biggest difficulty by using the mooring mast and getting airships safely to land and away again without a great handling party. He believed the rest of the difficulties could be got over. Sea sickness, noise, jolting, and all the nasty incidents of travel would be done away with, and he believed people would be prepared to pay whatever they had to pay for this speed and comfort, and it would be an economy to them having regard to the saving in time. There was no reason at this stage to discriminate between airships and aeroplanes. They were not in competition, and the pushing forward of the one would no doubt assist the other. The important thing was to get started as soon as possible commercially on both. It was about 500 years since we started out on an exciting adventure on the sea, and we did it to some purpose and secured a commanding position on the globe, and now we had another new element to conquer and the right sort of people to conquer it, and he had no doubt we would succeed.

The CHAIRMAN said as Commodore during the war, Admiral Hall was responsible for the whole of the submarine service in the British Navy, and it would be of great interest if he would state what he thought of the airship co-operation with the submarine service during the war.

Admiral HALL said the problems now facing the rigid airship were very similar to those which confronted submarines in 1904. We had then vessels of 100 tons displacement, and by the time the war ended the difficulties of submarine navigation had all been solved and the displacement of submarines had risen to nearly 3,000 tons. He did not see why the airship experience should not be the same, but since the conditions of the two services were so similar, he missed from the very interesting Paper just read what he believed to be the most important factor, and that was the question of personnel. The greatest difficulty he had had was to find officers—commanding officers in particular—to keep pace with the great strides in material, to get the best out of the very large and complicated vessels provided by the ingenuity and originality of the constructive departments.

The war has proved that courage, pluck, the joy of fight, is the common attribute of nearly all the men of our race. This is one thing, but the power of withstanding long periods of severe strain, of even desperate suspense, is quite another thing, and only those who have in peace developed an iron nerve, power of will which nothing can shake, can hope to achieve success in war in command of a large airship or a large submarine. It is two-o'clock-in-the-morning courage that is required, and that for the whole of the flight, and this is the strongest argument for the development of the commercial airship and why it is to be hoped that the Government will support any such scheme as that to which Sir Alan

Anderson has just referred. A peace fleet of commercial airships would provide a corps of officers, air pilots and navigators without which a fleet of war airships could not be efficient for a very long time—until, in fact, these officers were trained.

Believing as he did that if we were unfortunate enough to have another great war this would largely be decided in the air, it seems vitally necessary not to neglect any arm of the air service. The rigid airship had great value as a counter to submarines. Our submarines in the Heligoland Bight during the war cordially disliked the German Zeppelins on account of their endurance; they did not, like aeroplanes, come and go quickly, and all the time an airship was in sight it was impossible to come to the surface to charge their batteries or even to take sights to fix their position. The future rigid carrying probably several aeroplanes ready to slip and bomb any submarine sighted would be an invaluable protection in many seas, in addition to the other warlike functions required from airships. The most economical way of developing these in peace appeared to be by means of their commercial use, and some form of Government subsidy would be amply warranted by the asset such commercial development would give us in the experience gained in design of the ships themselves, and what is of far more value, in the training of the personnel in their management and in air navigation.

Mr. C. I. CAMPBELL (who was announced by the Chairman as the designer of all the Government rigid airships in this country) said the Paper covered a great deal of ground and did not leave many points for discussion. In dealing with the length-over-diameter ratio, the Author stated that "the more nearly spherical the form, the lighter would be the structure." One or two points came in to interfere with any great gain in lightness of structure if this ratio were decreased too much. One was that more than a certain proportion of the total lift could not advisedly be put in one gasbag, otherwise there would be considerable risk of losing the airship in case any one gasbag were damaged. We were, therefore, tied down to having perhaps not more than one-tenth of the total buoyancy of the ship in one bag and so there must be at least ten gasbags. As the ship was made more nearly spherical the shape of the gasbags became more and more uneconomical, and the weight of the main transverse frames increased also. On the other hand, if the bulk of the resistance was due to skin friction it was obvious that the surface area must be cut down as much as possible. It was a very long range shot to go from a two-million to a ten-million c.ft. ship at present, but he was confident that, as stated by the Author, the gain in going to the big ship was a good deal greater than appeared in the table. As an example, a big and a little engine each required only one man to look after it, so there was a considerable proportionate gain in the big ship as regards weight of personnel. The same held good with regard to all the little fittings about the ship both as to weight and resistance. He could not quite understand what the Author said about studying the performance of a ship from the point of view of carrying with the utmost economy unit weight unit distance at unit speed. If they wanted to travel at unit speed they would not go in airships. The Author stated airships having the lowest possible resistance were the best, but during the war the chief demand was for airships able to go to the greatest heights, and that would probably continue to be a requirement for service airships, and it would drive us, as it did in R.38, to sacrifice a little on resistance to get more lift. Speed would probably come to be based on experience as to what weather was likely to be met and what speed would be best for safety and regularity of running. In the long run, meteorological conditions would determine that very largely. Dynamic lift certainly fell off as the size of the ship was increased, as stated by the Author. Speaking of the outer cover, one came up against the thing which usually made dynamic lift desirable—the superheating or the occurrence of differences of temperature between the gas and the surrounding atmosphere. It certainly had an important influence

upon the flight of R.34, but he was anxious not to exaggerate the importance of it, because with improvements in outer covers it would be tremendously reduced. There were several schemes for reducing superheating that had not been tried yet, and we need not reckon on having to fly at considerable angles on account of the changes of temperature. The method recommended in the Paper of having the tension in the outer cover maintained by the dope when dry and by the fabric when wet, he understood, gave good results in aeroplanes but had not proved itself yet in rigids. It did not sound ideal, but might turn out all right. It would certainly be better if a really water-tight dope could be obtained—a film which did not stretch when wetted.

Wing Commander CAVE-BROWNE-CAVE said the lecture was of value as it gave a well balanced perspective view of the difficulties involved in airship construction. Those who were daily dealing with individual difficulties of detail were rather liable to omit to keep clearly in mind the general principles. The Author described the variations of the resistance of an airship in a manner similar to that in which the resistance of a water ship was treated. He separated the skin friction from the resistance due to the form. If that were found to be the correct procedure it would modify their present views, and he would like an expression of opinion from a gentleman from the National Physical Laboratory on that point. He did not quite agree with the Author that a dope of considerable stiffness or rigidity should be used to prevent flapping or vibration of the outer cover. Very large unsupported areas of fabric were being dealt with, and it was difficult to conceive how stiffness of the material could contribute in a serious degree to the rigidity of the cover. In describing the function of the outer cover the Author had omitted to explain that a most important function of the pigment or the dye in the dope was to protect the fabric from deterioration by light. He agreed most strongly with the Lecturer's remarks regarding engines and propelling machinery. The thing that caused most anxiety to the actual flying officer was a doubt as to the reliability of his machinery. If it were possible, as the Lecturer suggested, to standardise power units, and if a power unit could be detached from the ship and replaced by another complete unit it would be a great advance, as power units could then be developed almost independent of the remainder of the ship. It would be the duty of officers responsible for the design and development of machinery units to test them out thoroughly apart from any question of their use in the ship. Now the war was over and the flying that could be done for the present, at any rate, was restricted, the only extensive machinery tests which could be made must be by building a power unit, rigging it up to represent flying conditions as far as possible and trying it out to destruction. This would give experience almost equivalent to flying experience and twenty times as rapidly. He agreed with the Lecturer's remarks on the relative danger of fire from the fuel and the gas. The danger of fire connected with the gas, setting aside attack by hostile aircraft, was extremely small. Hydrogen required a good spark or a flame to light it, and reasonable precautions would prevent its ignition. The petrol tanks, however, had to be distributed over a large proportion of the ship, the petrol pipes ran the whole length of the keel and down to the engine cars, and the danger from accumulations of petrol vapour, although not great, was more than that from gas. If it were possible to use paraffin—which was well below its flash point—safety in airships would be greatly increased. To use paraffin a slightly heavier engine had to be fitted, but so long as the fuel burnt per h.p. was not greatly increased the increase in the initial weight of the engine was comparatively unimportant. He was anxious that investigations should proceed on those lines.

The Lecturer has referred to a Paper read by him last year. In the discussion of that Paper Squadron Leader Pritchard had accused him (falsely, of course) of being biased in favour of the non-rigid rather than the rigid ship. He could not, therefore, now refrain from drawing the Author's attention to the last section of

his Paper in which he recited some of the remarkable achievements of airships, most of which had been performed by non-rigid ships.

He considered that the Paper was of very great value and that the Society owed the Author a debt of gratitude.

Mr. H. B. PRATT (Vickers Ltd. Airship Dept.) said he was particularly interested in the part of the Paper on superheating. The conclusions the Author had given were the reasoned results he had reached after a great deal of flying, and would be of great value as a guide to designers when giving consideration to that point. He agreed with Commander Cave that one of the most interesting subjects dealt with in the Paper was that of propulsion. The question of the distribution of the power units and the system of propulsion generally was the most imperfect part of airship design. The design of the hull with present materials had probably reached finality, but the machinery was far from that stage. The Lecturer referred to the interesting possibility of using steam power. The chief advantages of using steam power would be that it would enable the whole of the steam generating plant to be concentrated into one part of the ship, which would probably lead to more efficient running, and less need for attention. The steam could be used for heating and cooking. Steam propulsion was quite efficient, particularly with high pressure superheated steam. He thought that method of propulsion would be worth going into in the future. He believed experiments in that direction had been carried out in America. Sir Hiram Maxim, on his first aeroplane, had a steam engine. It weighed under 2lbs. per h.p., and the boiler, with water, only weighed 2.8lbs. per h.p., but fuel consumption was 0.82lbs. per h.p. A great objection to his plant was that the engines were not condensing, and a great weight of water had to be carried. There should be no essential difficulty in developing a light type condenser which would only require the amount of water to be carried necessary to make up for leakage and losses in the working of the engine.

The CHAIRMAN said they had present Mr. Mitchell, General Manager of Messrs. Short Brothers, who were building R.37, one of our latest types, and also R.38, the very latest type, which embodied all our new designs. He would be glad if Mr. Mitchell would contribute some remarks.

Mr. MITCHELL said the Lecturer laid great stress on adopting the most perfect streamline form. He did not agree with that. When it was looked into from all points of view the best all-round form would probably be found to be a good deal fuller than the most perfect streamline form, owing to the gain in displacement more than counterbalancing the slight extra resistances. The Lecturer also stated that the weight of the hull increased in a less ratio than the displacement. Theoretically, when one got beyond a certain size of ship, as the ships increased in size the hull should increase to the fourth power of the linear dimensions, that is, if we compare two ships equally well designed. With a large ship there were many counterbalancing advantages which helped to keep down the weight, but on the whole he thought a ship of the present size, say three million cubic feet capacity, could be designed with as light a hull in proportion to the displacement as would be the case in a ten million cubic feet ship.

He thought that at the end of the war this country had picked up the Germans in the design of rigid airships, but since then we seemed to have marked time very much. All the airship building establishments had been going along very slowly, and meanwhile the Germans had designed a commercial ship and got it built, and it had been running for many months, apparently very successfully. He thought the builders in this country were confident that they could turn out a ship to meet the required conditions for commercial work. The difficulty was largely one of finance, and it was to him even more extraordinary, that the Germans in their present financial condition could find the means of turning out this airship

and running her commercially whilst we could not owing to lack of financial support. It was to be hoped that the enterprise for which this country had always been famed would not fail us now and that some one would come forward now and get a ship built for the purpose. It had been suggested that existing naval airships, designed probably two years ago, should be used for a trial commercial service, but we could not in that way compete on favourable terms with the Germans. What was wanted was a ship or ships designed on the latest lines and built quickly.

Commander LAND (Assistant Naval Attaché at the American Embassy) said he knew comparatively little about the subject under discussion. His being called upon to discuss it reminded him of a game played in the American Navy called "passing the buck." The man was there who could have made some useful remarks (Commander Dyer), but apparently he was over modest or his hind legs were not strong enough for him to stand on.

He rather failed to see why in the designs now being prepared one should differentiate between rigids for naval and military purposes and commercial purposes. He thought more progress would be made and the designs would probably be more successful if they worked along jointly with the same ideas; what was good for one was good for the other. The passengers' equipment could be taken off and bombing machines and small guns put on.

The tendency in rigids to get the major diameter much closer to the bow was correct in principle; a somewhat analogous tendency had been found to be correct for surface craft, for battleships, and particularly for submarines.

In Washington they made wind tunnel experiments with three Parseval models —one with the length-over-diameter ratio of 6.14, the second with the foreshortened shape somewhat on the lines of the Bodensee and a length-diameter ratio of 5, and the third with the major diameter 10 per cent. further aft than in the second model. The resistance of the first being taken as 100, that of the second was 86, and the third 89 per cent.

The National Physical Laboratory and those in charge of model basins both here and in America should carry out further experiments on the questions of location of the cars, the construction and location of fins, and streamlining; the models should be tested with and without appendages and with the appendages in different location with respect to the hull.

From model basin tests on submarines the streamlines sometimes followed the hull in a rather unexpected manner. Great care was therefore necessary in properly locating excrescences of any kind, be they fins, cars, rudders or wires, in order not to interfere with the proper streamline flow; interferences with this normal flow set up eddy currents, pockets, etc., materially increasing the resistance and thereby reducing the speed.

It was found in installing bow hydroplanes and stern hydroplanes on some submarine hulls that better control and less resistance resulted if the installations were well clear of the hull rather than very close to it. This clearance allowed more natural streamline flow and the results might well find similar application in the location and installation of appendages on rigids. There was room for further scientific experiment. The Parseval experiments he referred to were bare hull.

As the Lecturer well brought out, much of the resistance, which he called parasitic resistance, was in the fins, the wires and the position of the cars, *i.e.*, appendage resistance. That was where the designer had to look when trying to get high speeds and a better ratio of lift.

He would like to know what was meant by a "just stable enough" ship.

With regard to the comparison between R.33 and R.23, if the larger ship had a smaller turning circle it was an improvement in navigability, and if the fin areas of the two ships were stated, the point would be more forcibly brought home.

He agreed that the danger of fire from the gasoline was greater than the danger from the gas in the gasbags, but he did not see the point of using a gas (hydrogen) which was very explosive, if it were possible to avoid it. If there were a fire it did not necessarily mean complete destruction, and if hydrogen were not there the fire might be put out and the ship saved. He believed the Author rather "over-proved" his case in this respect. If helium were available he very much favoured its use in lieu of hydrogen.

Mr. J. R. PANNEL (*communicated*): The Paper which has been read by Squadron Leader Pritchard is of vital interest in the present stage of airship development, and in view of the Author's extensive flying experience may be regarded as carrying great authority; but the present writer is of the opinion that the point of view adopted in considering the resistance of the hull is, in certain respects, open to objection.

Under the heading "Form" it is stated that the total resistance may be split into three parts, viz. :—

(1) The small portion due to and proportional to the area of the maximum cross section of the hull.
(2) A large portion due to the skin friction of the hull and proportional to the surface area.
(3) Appendage resistance.

The sum of items (1) and (2) represents the total resistance of the hull, which, neglecting interference, may legitimately be separated from item (3); it is the validity of the proposed sub-division of hull resistance which is questioned.

Numerous experiments have been carried out on models to determine the proportion of the resistance due to the pressure of the fluid, the method being to measure the pressure in a hole in the model (which gives the pressure normal to the surface) and to determine by integration the component of this force along the axis of the model (the "Form Resistance"). The difference between this quantity and the total resistance is due to the tangential force or skin friction.

Experiments carried out at the National Physical Laboratory show that this "form resistance" is a very small proportion of the total (sometimes in the neighbourhood of zero) for bodies as different in form as the hulls of airships R.23 and R.33 or the envelope of S.S.E.3. But it should be noted that, on models, the R.23 form has a resistance coefficient of 0.019 as compared with 0.011 for R.33 and 0.008 for S.S.E.3. Since the resistance is found to be almost entirely due to skin friction it is obvious that *the skin friction depends on the form of the body.*

It is probable that the skin friction is affected by changes in the structure of the flow which occur when the form of the body is varied, so that it is not possible to calculate for such bodies a skin friction coefficient dependent only on the roughness of the surface, as is done for plane surfaces.

The writer is of the opinion that there is neither theoretical nor practical justification for the separation of resistance into "skin friction" and "form" resistance.

With regard to the ratio of length to diameter experiments have been carried out at the N.P.L. on models,* which show that this ratio may be reduced to about four and a half without increase of resistance, in fact, such a model had a lower resistance than any model then examined. This model consisted of an elliptical head as employed on R.33, two diameters long and a pointed tail 2.6 diameters long.

* Report of the Advisory Committee for Aeronautics R. and M. 607.

With regard to the relative facility for turning of R.23 (23 Class) and R.33, the recent full scale experiments give the following values.

Rudder Angle (degrees).	Diameter of Turning Circle. R.26 feet.	R.33 feet.
5	15,800	7,340
10	9,400	5,816
15	6,800	4,738
19	6,300*	4,000*

*Estimated; full helm.

The Author states in the section on "Fins" that "although the 33 Class is of twice the capacity of the 23 Class, the turning circle of the former is only about half as great as the latter." It will be seen from the table that this is only true at small rudder angles.

In comparing the turning performance of ships of different size it is convenient to calculate a "turning coefficient" which is the ratio of the diameter of the turning circle to the length of the ship. At full helm the turning coefficients are R.26, 11.8, and R.33, 6.2, the values being in the ratio 1.9 to 1.

With regard to dynamic lift it may be useful to consider rather more fully the effect of inclining the axis of the airship to the horizontal. Imagine the ship flying on a horizontal path at a positive angle of pitch (*i.e.*, bow up) α, at such a speed S, that the vertical component of the force on the hull plus the vertical component of the airscrew thrust balances the amount heavy. Now consider the motion of the ship when a weight is released making the ship light and the angle of pitch and speed remain respectively at α and S. The airship will rise at a rate greater than $S \sin \alpha$ until (neglecting extraneous effects such as superheating, deposition of moisture, etc.) sufficient gas has been lost to give static equilibrium; under these latter conditions the rate of rise will be $S \sin \alpha$. The dynamic force and the component of the thrust will force the ship above her equilibrium height until so much gas has been lost that no further rise takes place, the amount heavy being equal and opposite to the vertical component of the dynamic force plus the component of the thrust.

With regard to the necessity for the use of "up elevator" when the ship is light and flying nose down, this behaviour appears to be the logical outcome of longitudinal instability; but the subject merits treatment at some length and the present occasion is unsuitable.

The question of water ballast is one of considerable importance and it would be useful to have the Author's opinion on the following points.

The present writer's flying experience is limited, but it has included flights in four different rigid airships and he has been impressed by the quantity of water ballast which is taken up on each flight and brought safely back to the shed. Except for the effect of superheating, this result might be expected since the consumption of fuel tends to make the ship become steadily lighter during the whole flight. In the great majority of flights the only ballast released is that employed during landing; the quantity is always a small proportion of the amount carried, and often none at all is expended. It is probable that as more experience is gained and the design of airships improved, still less ballast will be required for landing, since use of such ballast is more often due to an error of judgment on the part of the pilot than to abnormal atmospheric conditions.

The commercial airship must carry as much useful load as possible and the following figures show how important is the weight of water ballast usually carried compared with the probable weight of passengers and cargo.

Captain G. M. Thomas has supplied some figures for the amount of water

ballast usually employed on R.33, of which airship the disposable lift (comprising passengers, crew, cargo, fuel, ballast, etc.) is about 24 tons.

The normal amount of water ballast carried at the commencement of a flight is about 6 tons, and the amount which is regarded as a minimum is $3\frac{1}{2}$ tons. Of the 24 tons about 16 tons are available for cargo (or passengers) and fuel.

For the sake of argument assume that a journey of 1,000 miles is to be made in 24 hours so that a speed of 41 m.p.h. over the ground will be necessary. At an air speed of 45 m.p.h. the petrol consumption on R33 is about 400 lbs. per hour or $4\frac{1}{2}$ tons for the flight. As meteorological information becomes more complete it will no doubt be possible to avoid many adverse winds so that an allowance of 9 tons of petrol and $\frac{1}{2}$-ton of oil for the 1,000 miles would probably suffice. Under these conditions the weight of cargo would be $6\frac{1}{2}$ tons.

If the minimum of $3\frac{1}{2}$ tons of ballast is carried it is equal to nearly half the weight of cargo; if the ballast were reduced to 1 ton, which should be sufficient for landing, the cargo carried would be increased to $1\frac{1}{2}$ times its original value.

A part of the fuel could be carried in tanks with quick release valves, and used as ballast in cases of emergency. In the exceptional case of a ship being heavy on reaching the landing ground part of the cargo or some of the crew could be landed by parachute. The suggestion of using petrol as ballast may appear wasteful, but it is assumed that it will only be very occasionally employed, and petrol is relatively inexpensive as compared with cost of hydrogen and other charges.

In operating an airship in this manner it will probably be necessary to employ petrol waggons which would follow the ships to the landing ground before the flight. Petrol could then be readily transferred if it were found at the last moment that the airship was too heavy or too light.

The only remarks that I should like to make on Major Pritchard's Paper are really in amplification of some of his statements.

He referred at the end of his lecture to the progress made by the Germans since the Armistice in the construction of the Bodensee, and to the organisation of their works at Friedrichshafen. When the Allied Commission visited these works in January, 1919, there were no ships of the small size of the Bodensee in any of the sheds. Unless the Germans used parts of L72 and L73, which were in various stages of construction, this means that the Bodensee was entirely constructed in about five months. This, of course, is much slower than during the war, but nevertheless is remarkable in view of the shortage of material, etc., from which the Germans suffered. The works at Friedrichshafen are very well laid out for the production of airships, and in addition have the engine works of the Maybach Co. in close proximity.

The other point to which I should like to draw special attention is the question of the cost of rigid airships. During the war cost was of secondary consideration compared with the necessity of rapid development of the airship to attain the required conditions. Commercially, however, the first cost is of prime importance, and anything that can be done to reduce this will materially assist in the development and use of these ships. Speaking from a designer's point of view, there are several items in construction which could be considerably reduced in price. Major Pritchard mentions one—that of the gasbags. The discovery of a non-expensive substitute for goldbeaters' skin is essential, and the development of a cheap method of applying the substitute desirable. In addition, there are the duralumin girders. Duralumin, according to a quotation in "Aeronautics" in October, 1919, costs approximately £615 per ton. Steel, on the other hand, in the special sections which would be used in airships, should not cost more than say £100 per ton, so that assuming the quantity of material used to be the same, there is a clear gain of £500 a ton on material. The amount of scrap in

steel would also be less. The cost of erection should also be considerably reduced from the present figure.

It is considered, therefore, that to make airships paying propositions such as outlined by Sir Alan Anderson, efforts should be made in the direction outlined above rather than on the line of producing—at any rate, for the time—ships costing more per ton of disposable lift than the present figure.

Mr. F. Fox said he commenced airship work in 1893, and all the improvements he had suggested had been taken up by all nations. He understood the non-actinic dope which he introduced seven years ago had been used in the Service, and he would like to know the results. He found the non-actinic less hygroscopic than the cellulose-acetate dope. Nitrous cellulose dope was of a more permanent nature and would draw the fabric up to a far greater degree of tautness, equal to any dope on the market, and being taut it was less liable to skin friction. With regard to fire dangers, it was known that hydrogen was non-inflammable except when mixed with air or oxygen. He suggested that between the hull and outer cover there might be introduced dioxide of carbon. It might be possible to have the pressure of dioxide of carbon against one of the balloons of dry fabric causing the dioxide of carbon to enter the balloon and also to go out into the air. That he thought would avoid any fear of ignition.

Mr. A. W. Johns (*communicated*): Major Pritchard's Paper is so interesting and covers such a wide field that it is difficult to offer criticism on the whole of it. The following remarks are therefore confined to the portions dealing with resistance and fins.

Some years ago Colonel O'Gorman, reporting on trials carried out on models of various airships, arrived at the conclusion that the most efficient airship was one in which the length was about $5\frac{1}{4}$ or $5\frac{1}{2}$ times the diameter. Major Pritchard suggests 6 times the diameter. The two results are therefore fairly in agreement. Both are obtained from considerations of resistance alone. Both neglect the question of aerodynamical stability which is also important. I take it the shorter the ship the relatively more unstable she becomes, and the more the elevators must be used to maintain a horizontal flight. The larger also must be the fins to render her stable. It would therefore appear probable that when the question of the ratio of length to diameter is considered in all its aspects—not only from the point of view of resistance alone—that a greater ratio of length to diameter than 6 will be found most efficient. The torpedo is a body whose motion through the water is in all respects similar to that of an airship through the air, and I believe it is the case that in certain sizes and marks of torpedoes it was found necessary to increase the length and also, therefore, the ratio length to diameter to obtain efficient stability at all speeds and conditions of running.

As regards the size of fins and elevators I have always understood that in early British airships the areas of these were determined from considerations of the sizes given to the fins and hydroplanes of submarines. This was natural since Captains Bacon and Sueter and many of the officers engaged in pioneer airship work in this country were submarine officers, and they realised that in a great many respects the problems in the two cases were exactly alike. Now the areas of hydroplanes in a submarine are determined to enable her to be controlled at exceedingly small speeds, say one knot, compared with, perhaps, 9 knots full speed. If determined for full speed they could be made much smaller in area. In the airship the condition, I think, approximates to the top speed of the submarine. There is not so much difference between ordinary and full speeds as in the submarine, and hence in early British airships the areas of fins and elevators were calculated on a supposition which gave too large a result.

The right determination of the size of fins and elevators is extremely difficult, and so far as I can see can only be settled in the completed ship. Model results

are of little value since the condition in which a ship starts on a swing in the vertical plane and her inertia becomes effective cannot be reproduced. In submarines it has been found that as the size increases more delicate clinometers are required so that the swinging of the boat can be at once detected and the hydroplanes worked to check it before it becomes serious. Major Pritchard also refers to the alteration in the shape of elevators and states the cruiser type of balanced plane has been adopted. Some years ago Professor Bryan pointed out in a paper before the Institution of Naval Architects that with such a plane hinged to the fin, the latter has a large pressure assisting the turning of the ship brought on it when the plane is placed at an angle. Part of the fin nearest the plane thus acts as a rudder (or elevator), and since its leverage about the centre of gravity of the ship is larger than the leverage of the inclined plane itself the fin effect on turning may be greater than the plane effects. If we look back to the old wooden line-of-battleships we find that the rudder was deep, very narrow and very efficient. Thus engineering history repeats itself.

THE LECTURER'S REPLY.

The most interesting technical points raised during the discussion have been considered as far as is practical in the order in which they were raised.

There is no doubt, as predicted by Mr. Campbell, that with the improvements in the reflecting properties of outer covers and improvements in ventilation between the outer cover and the gasbag, the degree of superheating experienced, for example, in R.34, can and will be considerably reduced. The matter, however, is of importance even in its reduced form. In the first place, for Service requirements, it is important that the variation in lift should be as small as possible, so that when, for example, an airship is out on a long patrol, it can, when desirable, fly continuously at a very low speed and thus economise fuel and increase the duration of patrol.

Decrease in dynamic lift with increase in size unfortunately aggravates this question. If ships of no larger capacity than R.34 were contemplated, it is probable that the improvements in outer cover at present in view would bring about the necessary reduction in superheating, but with ships of distinctly larger size superheating will probably again become a source of inconvenience.

The method of maintaining a constant tension in a rigid outer cover in both wet and fine weather, by the tension of the dope in fine weather and the tension in the fabric due to its contraction in wet weather, is admitted to be a very rough and ready method, and it would certainly be preferable if, as suggested by Mr. Campbell, some insoluble dope or varnish could be obtained which would not stretch in wet weather. Unfortunately, with nitro-cellulose and cellulose-acetate dopes, also with the various varnishes at present on the market, there appears to be little likelihood of obtaining such a dope film in the near future, and it is therefore necessary that any method, no matter how rough and ready, should be used to fulfil the requirements of the near future.

Mr. Pratt appears to be unduly pessimistic in his belief that the design of the hull structure of rigid airships has already reached finality. Naturally the percentage improvement in the future cannot be as great as in the past, as rigids already constructed have a disposable lift of 60 per cent. of the gross lift. Nevertheless, marked improvements are to be expected in the following respects:—

(1) Lightness of structure. This will be automatically obtained by reducing the length/diameter ratio, aside from the more economical use of materials.
(2) Lower resistance by improvements in streamline form.
(3) Simplification of structure from the point of view of cheapness.

The great gain to be anticipated in the propelling machinery is not so much

its improvement in performance as shown on paper, as in practical performance with regard to such considerations as reliability and reduction in the cost of upkeep which have already been obtained to a much greater extent in the case of the hull structure.

Steam power, although it exhibits certain most excellent features, suffers from the inherent objection insuperably connected with all methods of indirect power production, namely, lack of efficiency in fuel consumption.

Mr. Mitchell's contention that the ideal streamline form did not possess a sufficiently high block coefficient does not appear to be valid.

For airships, the most efficient streamline form is generally accepted to be the one which gives the greatest lift/resistance for any given speed. In other words, the form which has the lowest value for resistance/volume. The best form for airships is, therefore, that which has the lowest value of $R/\rho l'^2$ (Volume) $^{\frac{2}{3}}$ which is independent (nearly) of speed or size for a given form.

In ships like 33 or 38, an appreciable gain might be achieved by filling out the bow and stern without altering the length/diameter ratio, but this would be due to the fact that these ships are nothing like the most efficient streamline form. If, however, the N.P.L. figures are taken for the most perfect streamline form, namely, a hull with a length/diameter ratio of about 4.5, any filling in of the bow and stern to produce even a small increase in volume without altering the length/diameter ratio, would inevitably cause a very material increase in head resistance which would far more than counterbalance the small increase in lift. In this connection, the point raised by Mr. Campbell needs careful consideration, namely, that when the length/diameter ratio becomes lower than about 6, the ratio height of gasbag/length of gasbag becomes so large that a considerable amount of fabric is wasted, always assuming that it is necessary to allow, say, ten gasbags for safety.

The point raised by Commander Land with regard to the similarity between commercial and Service rigids for many years to come cannot be too strongly emphasised. Also the community of interest between the Service and commercial airship enterprise, also dwelt on by Commander Land, is very true.

The lecturer feels that his method of treating the resistance justified itself by extracting from the N.P.L. Mr. Pannell's interesting contribution to the discussion. Although Mr. Pannell's views are no doubt academically correct, the lecturer feels that it is of importance that stress should be laid on the fact that the majority of the resistance to the passage of an airship through the air appears to be due to skin friction, even if this may in turn be to a certain extent due to the form of the ship, and that the cross sectional area of the ship plays a very secondary part in the resistance.

With regard to Mr. Pannell's remarks on the question of ballast, the present practice is to carry ballast in two forms: —

(1) Emergency (landing) ballast, which is situated at the bow and the stern, and can be used either for trimming the ship by only releasing ballast from one end, or for quickly lightening the ship in the event of some emergency. This ballast should be in such a form that it can be released with extreme rapidity, and as it is frequently used at the moment of landing should not endanger the lives of the people below. The amount of water ballast necessary for this purpose is in the order of 3 per cent. of the gross lift of the ship. In tropical countries, where greater inversion temperatures would be experienced, a larger amount might be required. The amount of this form of ballast carried will naturally decrease with experience, as suggested by Mr. Pannell.

(2) Normal water ballast. Besides the emergency (landing) ballast, which

is situated at each end of the ship, a further amount is officially allowed for in this country, namely, 6.2 per cent. of the gross lift for rigids, and 3.2 per cent. for non-rigids. This allows the rigid to leave the ground in equilibrium and rise to a height of 2,000ft., and the non-rigid to leave the ground in equilibrium and rise to a height of 1,000ft. This ballast, as far as the internal arrangements of the ship will permit, is carried not far from, and symmetrically about, the centre of lift.

In the case of rigids, under practical conditions, probably only half of the ballast would be used for leaving the ground in safety, and the remaining 3 per cent. of normal ballast plus the 3 per cent. of emergency water ballast would, under normal circumstances, be retained through the flight of the ship as a necessary safety margin in the event of, for example, a gasbag deflating or one of many unforeseen occurrences, such as very excessive superheating or a heavy snowstorm, etc.

The disadvantage of carrying only petrol ballast is mainly its inflammability, which prevents its being released from an airship with any degree of safety without dropping it complete with its containing tank. This would be most dangerous when flying over populous country or when landing. A large proportion of the petrol is, however, carried in quick release tanks, so that in the case of an emergency, petrol as well as water ballast can be jettisoned, for example, when the ship is over the sea.

It cannot be too strongly emphasised that an airship for commercial purposes anyway, should carry an ample margin of quickly releasable disposable weight to ensure the safety of the passengers, and in such a form that it will not damage people on the ground. The suggestion of jettisoning cargo on landing, especially if this is in the form of passengers and their personal effects, cannot be too strongly deprecated. In the Author's view, it would correspond to the captain of a liner who, on finding that his ship draws too much water to enter a certain harbour, has his passengers and cargo thrown overboard to lighten the ship.

With regard to Mr. Johns' contribution, the most ideal streamline form is thought by the N.P.L. to possess a length/diameter ratio of about 4.5, but, owing to many other considerations, such as that raised by Mr. Campbell with regard to gasbags, and to the lack of height of airship sheds in general, it is probable that streamline forms with a length/diameter ratio of between 5 and 6 will be used for some time to come.

The necessity for sensitive instruments for registering rapidly change of path in large submarines also has its counterpart in airships. Likewise, in airships, it is of the greatest importance that any change in the path of the ship, either vertically or horizontally, should be detected and corrected immediately, as otherwise it requires a large amount of unnecessary correction. Delicate instruments should, therefore, be provided if possible which do not merely detect change in path but detect changes of pressure on the bow and stern of the ship which a few seconds later produce the change in path of the ship.

Mr. Johns' point with regard to the very efficient rudders of the old wooden line-of-battle ships is most interesting, and again finds its counterpart in the post-war German airship Bodensee.

The points raised by Mr. Cole are of great importance. The construction of the Bodensee in a little over five months compared to British standards of rigid airship construction, where most rigids have so far taken well over a year to build, is by no means rapid compared to German rigid airship construction. The rapidity of German rigid airship construction and the advantages obtained thereby cannot be too strongly emphasised.

During the war, since the time the Germans began to build their so-called super-Zeppelins, *i.e.*, Zeppelins of 2,000,000 cub. ft. capacity and over, more

than thirty such ships have been built, and the average time taken to build each ship, including flying trials, is roughly one ship per berth per 10 weeks. At their maximum activity, the rate of construction reached the extraordinarily low figure of one ship per berth per 8 weeks, including flight trials.

Rapidity of construction is of extreme importance. In the first place, new methods of construction and new designs can be rapidly put into practice, and the experience gained from their success or otherwise can be again rapidly incorporated in future ships. The steady improvements made by the Germans almost ship by ship—from L.31, which was distinctly inferior to the British R.33 class, up to the very efficient ships of the L.70 class—are most marked. The disposable lift/gross lift ratio was nearly doubled, and the speed increased by some 20 miles an hour. Secondly, from the point of view of cost, when rigids take a year or more to construct, the yearly capital charges of the construction establishment have to be borne by possibly one ship, while, taking German rate of construction, these charges would be divided among at least five ships. In the case of rigid airship construction, the capital charges are high, and this consideration has a marked bearing on cost. Assuming, therefore, that a fixed number of ships are required to be built per year, it can be laid down that it is much more economical to use as few berths as possible and construct rapidly rather than use a large number of berths and construct slowly.

The CHAIRMAN proposed a vote of thanks to the Lecturer and said such lectures by men of experience and technical ability went far towards helping on the development of their young and promising airship service. He considered the airship service had a very big commercial future, and he was convinced that in future years they would have airship services running round the world.

General BROOKE-POPHAM, in proposing a vote of thanks to the Chairman, said he had made nice remarks about the great work others had done in the airship service, with which he cordially agreed. But all those individuals would own that the person to whom the service owed more than to anyone else was Air Commodore Maitland. He, like the Lecturer, had a magnetic personality. It was due to him more than anyone else that the present development of aircraft, rigid and non-rigid, was due.

PROCEEDINGS.

EIGHTH MEETING, 55th SESSION.

The Eighth Meeting of the Fifty-Fifth Session took place in the Hall of the Royal Society of Arts, London, on Wednesday, February 18th, 1920, Mr. H. White Smith, C.B.E., presiding.

The CHAIRMAN said, before calling on Major Bishop to read his Paper on "Characteristics of Design Affecting Production, Operation and Maintenance of Aircraft," he would like to introduce him in a few words. Probably he was well known to nearly everyone there, but to those who had not the pleasure of his acquaintance, he might say that Major Bishop started his aeronautical career so far back as 1912. He took a considerable interest in the subject as far back as 1910, but he joined the Aircraft Factory in 1912 and after about two or three years there he proved so useful that the Inspection Department cast their eyes on him and took him away to serve on that work. He had been working on inspection since, and now occupied the position of one of the chief assistants to Major Outram on the inspection of aircraft. He was, therefore, well qualified to address them. He knew, first hand, the facts with which he was dealing, and they would listen to his lecture with the greatest interest, because he had studied the subject from the point of view of results. In the Inspection Department they had to look at things very critically, and he thought they would find in the Paper that the Author had given them the benefit of his very close observation of the subject.

Major PERCY BISHOP, Associate Fellow, then delivered the following lecture:—

CHARACTERISTICS OF DESIGN AFFECTING PRODUCTION, OPERATION, AND MAINTENANCE OF AIRCRAFT.

The advent of the use of aircraft for purposes other than warfare will involve the appearance of several additional aspects into the already numerous considerations which have to be applied during the evolution of the design of an aircraft.

During the recent war, designers were called upon to produce designs in which performance and manœuvrability were the foremost considerations, and sacrifices of other factors, including safety and stability, had to be made in order to attain supremacy in these directions. It is true that during the latter stages of the war matters concerning ease of production, the use of alternative materials and accessories, and facilities for maintenance did receive a certain amount of attention; but in view of the speed at which designs and production had necessarily to mature, the amount of thought which could be given towards such considerations was very limited.

To-day the aspects are considerably changed, and the following notes are prepared with a view to emphasising the importance of those factors which in the past have been restricted, but which in the future will tend to take precedence among the characteristics of aircraft. In these notes it is not proposed to touch upon the relative importance of safety, performance and stability, but rather to deal with the characteristics which interest those constantly engaged with aircraft, whether they be concerned in manufacture, operation, maintenance or repair.

The vicissitudes which aircraft are called upon to experience, even before their initial flight, are in some cases very peculiar, and unless these are catered for by the designer at the outset the industry will suffer very considerably from dis-

appointed users, thus antagonising the class on which it must rely for its future prosperity. It is a common experience to-day for an aircraft of good design and manufacture to live half its life before enjoying the pleasures of its first flight, owing to its unsuitability to endure the terrors of dismantling, storage, transport, and subsequent erection under all sorts of conditions.

There is no doubt that aircraft suffer far more depreciation when on the ground, especially when subjected to transport and re-erection, than when kept in continual flying use. In future possibly the majority of this country's output of aircraft will be exported, and consequently the above conditions will apply, not to isolated cases, but to a majority, thus emphasising the necessity of the design being so contrived that provision is made to withstand such conditions.

Apart from this, a little consideration on the part of designers and draughtsmen will very considerably ease the lot of all concerned in the production of the machine. Such consideration will always assist in reducing the cost of manufacture, accelerating production, and evolving a more serviceable machine.

Experience during the war has shown that a great saving can be effected by very careful consideration being given to preparation of detailed drawings, so as to avert such an excessive amount of alterations as attended all designs during the early stages of manufacture. It is a regrettable fact that the design of details in this country is generally left to junior draughtsmen, who as a rule possess very limited experience of shop practice or of the routine of producing organisations. This in principle is entirely wrong, as the drawings are always "key" or "pivotal" (to use a current term), and consequently demand the keenest attention and very thorough knowledge during their preparation.

Again, nearly all failures in the air are traceable to detail faults, and several otherwise excellent designs of aeroplanes have been doomed owing to detail defects.

The various aspects from which improvements in design appear to be beneficial are dealt with in the following order, which covers the stages through which the aircraft passes from its conception to its "write-off":—

1. Preparation for manufacture.
2. Manufacture and assembly.
3. Inspection.
4. Storage, packing, and transport.
5. Operation and maintenance.
6. Repairs and replacements.

1. Preparation for Manufacture.

The work involved in the preparation of a design for manufacture is chiefly connected with the design of details, and with the production of drawings. It may be of interest to deal briefly with general drawing procedure, especially in regard to the information which should accompany all drawings in order to facilitate the production of the part or component concerned.

In the first place, the drawing should be regarded as a complete specification of the article required. It should contain the following information:—

1. All necessary dimensions, with permissible errors in manufacture, including accurate development in the case of complicated bent-up parts.
2. Particulars of the material from which the part is to be made.
3. The sequence of operations necessary for the production of the part.
4. Details of any heat-treatment which may be necessary at any stage of the work.
5. Protective requirements to prevent deterioration due to atmospheric conditions.

6. Identification marks in order that the part may be identified during and after manufacture.
7. The component or type of aircraft on which the part is used.

Each drawing should be on a separate sheet of convenient size.

Many designers do not even now consider all the above information essential, and do not include such items as operations and protective requirements. Their view is that the shop staff know better how to produce the part than the designer or draughtsman; but although this is undoubtedly true in many instances to-day, it is contended that the process of manufacture should be considered by the designer at the time of evolving the design; and that if the design is so arranged as to require a specific method of manufacture, the particulars ought to be stated on the drawings.

Admitting the necessity for means of identifying parts, partial assemblies and components, it is essential that a suitable numbering scheme for drawings be adopted. The production problems of automobile engineering are very similar to those of aircraft, and it is almost universally agreed that the adoption of one single series of numbers for components, parts, or even pieces of parts, is the most satisfactory method of identification. This system involves a separate drawing of each part and of each piece of a part. At first sight this may seem to be a cumbersome procedure, but it proves of great assistance to those engaged in production, where attention has at certain stages of manufacture to be paid to each individual piece separately.

Take for example the case of a built-up sheet metal fitting made up of two or more pieces. For this we shall require :—

1. A drawing of the complete part as required for erection; and
2. A drawing of each piece comprised in such a part.

It is assumed that these drawings are produced on the lines indicated above, and that the information they afford is more complete than is now usual.

Such drawings will have other advantages besides being more generally useful during actual manufacturing operations. The work of ordering and laying out will be much simplified, as the accurate development of parts or pieces can be set out in such a way as to obviate the tedious operation of laying-out in the shops by staff, whose facilities and capabilities for the geometrical and mathematical work required, can hardly compare with those of a trained staff continually engaged in such work in the drawing office.

Further, the drawings will be of material assistance to staff engaged in the stores and despatch departments. The drawings of parts, partial assemblies, and components, should each contain their respective schedules, as such information is necessary to complete the specification of the article represented. No further schedules will be required, and this is particularly advantageous in eliminating the liability of errors during the incorporation of modifications which involve alterations to both schedules and drawings. Such modifications are inevitable during the experimental stage of aircraft manufacture. The system also has the advantage that it leads automatically to standardisation, whether of pieces, parts, or components.

Considerable economy of material, of machining, of labour, and of temper, can be effected in the preparation of detailed drawings by calling for current available materials, and utilising, as far as may be possible, standard sizes of bars, sheets, and tubes. Each detail should be so arranged that it may be produced economically from such standards. If the requisite sizes of bars, sheets, etc., be named on the drawings the information will be useful from a buying and store-keeping point of view.

This point may be made clear by an example or two. For instance, parts such as turnbuckles, forked-ends, engine valves, spindles, etc., which are usually

produced in quantity on automatic machines, should be preferably arranged so that the maximum diametric dimension falls just inside the standard bar diameter. This will reduce to a minimum the removal of redundant material for the whole length of the part before the forming is commenced, and will thus do away with waste of material and needless wear of cutting tools.

Another example is that of a tank, in which, if the maximum width of sheet from which the shell, the ends, or the baffles, are made, falls just outside the standard size of sheet, the result is either a larger sheet being cut uneconomically, or the introduction of an additional seam in the construction of the tank.

Propeller laminæ, long spars, longerons, and struts, also frequently give rise to difficulty in manufacture owing to timber being unavailable in the required dimensions. There is then no alternative but to introduce joints, which are expensive to make and unsatisfactory in themselves.

The drawings should also specify carefully the permissible limits of error in manufacture, whether these are required to safeguard the strength of a part or to secure interchangeability. In determining such limits consideration should be given to tolerances necessary for the various manufacturing operations. In the case of interchangeability, additional consideration is necessary to provide sufficient "allowance" for error in gauge manufacture; and in some cases yet further allowances must be made for small errors in the manufacture of master gauges. This matter is of particular importance in the case of hinges or joints at the junctions of components where interchangeability is essential. Frequently the dimensions in these cases are large, and errors in manufacture are correspondingly increased. In such cases it is not sufficient to arrange the limits so that the parts shall in theory assemble where one part is on the high limit and the other on the low.

In the case of wooden parts allowance must also be provided for shrinkage of timber and distortion.

The whole question of limits is very involved, and can only be briefly touched upon in this paper, but in order that the drawings may be complete, the statement of limits must be such as to constitute legal evidence of the requirements, both on the part of the supply contractor and as affecting the manufacturing or erecting shop staff when payment is made on a piece-work basis.

2. Manufacture and Assembly.

The cost of production has received little consideration in the past as a factor in the design of aircraft, but with the development of aircraft for commercial purposes it has been realised that serious attention must be given to it.

The phases passed through since the conception of heavier-than-air flying machines make an interesting study. Most of the pioneers of flying had but limited resources for making and building their experimental machines. Accordingly the fittings they designed were generally arranged in the simplest possible way, and produced at the least expense.

Later on, when flying became more general, experiments were no longer embarrassed by lack of financial assistance. Designers then began to use the best material and labour available, and concentrated their attention on reducing resistance and weight to a minimum; thereby improving performance, without eliminating any of the necessary requirements for safety.

It is perhaps fortunate that the development of aircraft passed through such a stage so early in its career, especially as the burden did not fall on the industry itself. It enabled the essential qualities combining to ensure safety and good performance to be developed very rapidly.

The next phase is that of a compromise, and represents the one which interests the industry to-day; the problem being to reduce the cost as far as

possible by designing to suit manufacturing facilities generally, without any retrogression from the advance arrived at in safety and performance. It is proposed to pass this stage under review, and to show how some at least of the manufacturing difficulties may be eased.

The extensive use of fittings made from sheet metal, which can be punched out correctly to shape, and which require but few subsequent operations to complete manufacture, is undoubtedly a progressive stage towards this end. Such a method of production is considerably cheaper than that of using forgings and stampings, with the unavoidable subsequent machining. Until quite recently there was much prejudice against the use of sheet metal pressings; this arose from the assumption that the punching operation produced cracks of a dangerous character upon the sheared edges, but it has been found that this danger can be avoided by taking certain precautions, namely, the trimming-up of all edges where stress is likely to occur, and the removal of small cracks which might develop and cause trouble. For small holes the punching operation should be always followed by drilling or reamering.

In adopting such a method of production the standardisation of shapes of parts, or pieces of parts assists very materially. The cost of die-making and setting-up represents a very high percentage of the total cost, and consequently the number of shapes required should be kept down to a minimum. This can be achieved by so arranging the shape of a blank that other shapes may be cut from it by means of another shearing operation to cut away the redundant portion.

Another feature which perhaps has not been realised is the fact that the manufacture is simplified in the case of "right-hand" and "left-hand" parts. The blanks are always flat at this stage of manufacture, and the subsequent bending operation will determine the "hand." In the case of stampings, two dies are usually necessary, which not only involves setting up the dies twice, but also duplicates the number of jigs and subsequent operations.

The use of sheet metal fittings has the further advantage that the sheet from which the blanks are punched serves excellently as the locating portion of a jig for subsequent operations on the blank, such as drilling, etc.

Another important advantage of sheet metal construction which is particularly evident to-day is that it suits manufacturing conditions, no matter whether large quantities of the same part are required or merely the number necessary for one experimental machine. If the quantity does not justify the making of press tools, the blanks can readily be "nibbled" out from sheets at extremely low cost.

The combination of a number of blanks bent to desired shapes and connected together by rivetting, welding or brazing, is quite a cheap method of manufacture. In designing such fittings care must be exercised to ensure that the process of normalising the material to remove strains, caused through bending or welding, is capable of being carried out, without involving prohibitive distortion of the final shape required.

From the manufacturer's point of view standardisation is of the utmost importance, and too much stress cannot be laid on the necessity of giving it the utmost consideration in the early stages of the design of detail parts. Holes, screw threads, angles, tapers, and even radii of corners (where a machining operation is required), should be of standard dimensions, and the minimum variety of such sizes consistent with efficiency should be called for. This will result in limiting the number of sizes of drills, taps, dies, broaches, reamers, gauges, spindle tools and cutting tools generally; and also in some cases in an economy of setting-up operations.

The average number of tools and gauges required when manufacturing any particular design to-day, is unnecessarily high, and can be materially reduced without detriment to the efficiency of the machine itself.

In the design of covered components, one of the most prevalent difficulties which occur in manufacture is that of distortion, and it is essential that the structure should receive consideration from this point of view in the design. The strains of fabric doping, initial tension in bracing wires, shrinkage of timber, and bedding down of metal fittings on to timber, all tend towards distortion, which hampers quick erection, destroys interchangeability, and may well result in rendering the component unserviceable.

One of the greatest difficulties of erection experienced to-day occurs at the later stages of assembly, and that is the large extent of hand fitting which is necessary in the fitting of cowlings, connecting up of pipings, controls, and the fittings of accessories generally. This is due to the fact that drawings are usually not considered necessary for such parts, and the design is left to the shop staff to decide at the time of erection. The contention is that complete drawings should be made of all parts, and more particularly that the operation of assembly should then receive attention. If the dimensions of such parts are difficult to determine on paper, the use of "mock-ups" should be resorted to for this purpose. This practice also usually tends to the devising of more satisfactory arrangements, as regards both erection and functioning.

It is possible to incorporate in the design many other features which will simplify the erector's work and permit of increased accuracy in truing-up. As instances, fittings may be made self-aligning by means of universal joints or in other ways; strut fixings, wiring plates, etc., may have their securing pins arranged to hinge in the most convenient plane for lining-up; and multiple connections (hinges, for example) may be arranged to register on one of their number with ample clearance in the remainder.

3. Inspection.

The future of British aircraft depends very largely upon the maintenance of their acknowledged existing supremacy as regards both safety and reliability. This position has been won, firstly by sound design, both structural and aerodynamic, and secondly by ensuring that the actual aircraft comes into existence and continues to exist in the form intended by the designers.

It is clear that the first requirement necessary for carrying out any examination is adequate access to all important members and organs of the aircraft.

One of the peculiarities of aircraft design is that the performance very largely depends on securing clean, uninterrupted exterior surfaces, and on the streamlining of shapes which would otherwise increase head resistance; thus all structures and mechanisms tend to become hidden from external view by cowlings, coverings, fairings, etc. There is, however, no reason why such coverings should not be made easily detachable, or other provision made for purposes of inspection, without incurring any appreciable increase in head resistance.

It is realised that in the special case of planes this procedure is in practice prohibitive. When doubt arises as to the airworthiness of a plane which has been a long time in store, or has been transported from place to place, it may be necessary to strip and recover the component.

In any case, however, the more vital parts should be easily accessible, so that periodic examinations and adjustments may be carried out. Such inspections are demanded daily by the Air Navigation Regulations before passenger flights may be made, and provision should therefore be made to enable the ground engineer to satisfy himself of the safety of the aircraft in the shortest possible time.

One of the most important items in construction is the control mechanism, which should be carefully studied in this connection. Where controls are carried inside planes, doors or windows should be provided to view all pulleys, levers, and connections, in order that correct alignment, security of attachment, and

wear of cables can be safeguarded. Such inspection doors or windows should be so arranged that the whole of the run of the cables can be examined through them, in order to see that they run clear of obstacles such as ribs, struts, cross-bracings, etc.

To facilitate the attainment of these conditions sight holes or gaps should be employed to ensure :—

(*a*) The correct bedding of struts in sockets or on to other members;
(*b*) Sufficient length of engagement of screwed parts;
(*c*) The correct positioning of internal blocks in hollow built-up spars or other main members, as for example those constructed on the " McGruer " system.

Unless some such provision be made it is impossible, once the parts have been erected, to discover if these points have been attended to.

Particularly in the case of the power plant installation, periodic inspection is essential on account of the prevalence of leaks in petrol, water, and air systems, and the breaking or " shorting " of ignition wires caused through vibration or landing shocks. It is therefore absolutely necessary that the question of accessibility should be given the utmost weight. Improvements, in the form of quickly detachable cowlings, provision of sufficient inspection doors locally to petrol cocks and connections, or arrangement of the pipe lines or run of engine controls in such a way that they may be easily inspected, are essential.

Whilst dealing with the question of installation piping, it appears opportune to emphasise the importance of marking the various pipes for identification purposes. There is a standard method of painting the various pipes to denote whether they are for oil, water, air, or petrol, viz., red for petrol, yellow for compressed air, black for oil, blue for water, white for air speed tubing, and yellow and red for air pressure for petrol feed—and such first-sight distinction is an invaluable asset when checking a complicated installation system.

The work of an inspector can also be facilitated by the elimination as far as possible of such processes as welding, brazing or soldering, especially where the strength or security of the parts so treated is important. It is obvious that, after the operation has been performed, such a process cannot be certified as having been correctly carried out. Moreover, a selective test to destruction is not considered a sufficient guarantee, owing to the great degree of variation which can occur in such processes. Even with the " dip brazing " method the retention of the correct analysis of the brazing metal cannot be guaranteed, as the difference in the melting temperatures of the ingredients causes the zinc to evaporate away faster than the copper, so that even with frequent additions of zinc, and check tests at each addition, the constitution of the bath cannot be regarded as even approximately uniform.

A difficulty experienced in checking the truth of erection of an aircraft is to find datum surfaces or points from which to begin the series of check measurements. The provision of a horizontal cross and longitudinal member at some convenient point in the structure will serve to establish a level in both directions, and allow measurements to be based on this datum.

4. Storage, Packing and Transport.

The difficulties encountered in the storage, packing, and transport of aircraft components, and the consequent damage experienced during recent years, have been very great. The principal reasons are :—

Firstly, the fragility of the parts, necessitating the most careful methods of handling, packing, and storing;

Secondly, the sizes and awkward shapes of the components and parts demand

a large amount of space, both for storage itself, and as adjustment room for manipulation in the store; and

Thirdly, the difficulty of supporting the component or part when stored or packed to prevent damage due to chafing or distortion.

To meet such contingencies there appear to be two alternatives; on the one hand to provide special packing cases for each of the components or parts, which would render them immune from such damage; or on the other hand, to relieve the situation by refraining from the use of such fragile or large components, and make special provision in the way of supports, etc.

The first alternative would obviously be impracticable as a general measure, on account of the excessive cost involved in making the cases, although in certain cases such as engines, propellers and instruments, such practice is unavoidable. The second alternative can, however, be taken advantage of to a large extent, provided consideration is given to the question at the time of design.

The average covered component is incapable of being stored, packed, or transported, without receiving injury of some nature, owing to the impossibility of supporting it at favourable positions of its structure.

The addition to such a component of some form of projections by which it could be supported or secured would be invaluable from a transport and storage point of view. In addition, the designer would then know definitely the conditions to which the component would be subjected, and could arrange the local members of the structure to take the corresponding stresses.

The adoption of permanently built-up structures such as undercarriages, V-struts, cowlings, and fairings, should be avoided as far as possible to meet this end, and such forms should be superseded by structures which could readily be dismantled to convenient sizes and shapes for storage and transport purposes.

The limitation of sizes of components should be governed by the conditions of existing methods of transport, where such restrictions as heights of bridges, lengths of trucks, lorries, or trailers, have to be complied with. Considerable difficulty in transport has already been experienced in this direction, and the existence of prohibitive sizes of components has frequently led to extensive trouble and excessive cost in arranging transport. It becomes evident, therefore, that large components such as planes and fuselages should be capable of being dismantled to a more convenient size. In the case of planes with long chord measurements this could be effected by provision of detachable trailing portions, and long planes or fuselages could be made in sections with suitable jointing arrangements.

The use of detachable projections, such as levers and king posts, on covered components should also be encouraged with a view to meeting storage and transport facilities.

The storage of complete aircraft has been facilitated considerably by the development of folding wing arrangements, and it is encouraging to see that this practice is now being extended to small aircraft.

The deterioration of tyres during storage is possibly a point worth referring to under this heading, and even if it were considered that the incorporation of stands in the undercarriage design would be too great an encumbrance, the provision of suitable surfaces against which a jack or lever could bear would greatly facilitate the lifting operations, and enable blocks to be inserted to take the load off the tyres.

5. Operation and Maintenance.

The life of aircraft is a more vital matter in the case of machines required for civil purposes than in warfare. Fighting machines require to have all up-to-date

improvements embodied in them at the earliest possible moment, and thus existing designs quickly become obsolete because they are out of date, rather than because they are worn out. Further, financial considerations affect civil aircraft very closely, as the rate of depreciation in value must be reduced as far as possible.

It is most important therefore, that the question of wear and tear should receive attention at the time of design, and it is proposed to deal briefly with the conditions which largely contribute to depreciation, and to show how some of them may be ameliorated.

It is generally admitted that aircraft (excluding the engine itself) deteriorate more quickly when on the ground than when flying in the air. Especially is this so in the case of seaplanes, on which the effect of sea water is so pronounced.

Deterioration is to a very large extent attributable to atmospheric conditions, but it is considered that another important factor is that of damage and small accidents due to bad handling, climbing about the machine, and want of skill or care in the manipulation of the machine when on the ground and in hangars.

The life of the engine itself naturally depends to a very large extent on the length of its working hours, periodic attention, etc., but at the same time it, too, may be considerably affected by the treatment and conditions to which it is subjected, when not actually in use during flight.

The uses made of some of the structural members during handling or climbing about the machine would, if known to the designers, relieve them of a large amount of mathematical calculations. Such calculations are based on the assumption that the members and parts have to withstand only those stresses incurred in flying and alighting. As a matter of fact, parts which are amply strong on such an assumption may, and do, fail miserably under the unfair stressing they suffer during the handling of the machine on the ground.

It appears then that efforts will have to be made by designers to eliminate the liability of such "wear and tear" by utilising fool-proof devices to meet such contingencies. It must be remembered that the handling of the machine or its components is most frequently carried out by unskilled labour. In the case of a covered component in which the principal members are hidden, it is necessary either to give precise directions for handling, or, better still, to make the operation fool-proof by the provision of handles. Attachments such as these need not necessarily be an encumbrance to the machine either from the point of view of weight or resistance, provided they are carefully considered when designing the component.

One does occasionally see notices on fuselages denoting where the weight can be taken to avoid damage to its members, but this is not a sufficient safeguard, as evidenced by an incident witnessed by the author. Two men were assisting each other to lift at one point of a heavy fuselage, and they took particular care to lift it at equal distances on each side of the painted arrow denoting "*lift here.*"

Provision of steps and treads, not only for entering the machine but also for the use of riggers and mechanics when carrying out adjustments, is essential, and if duly considered in the early stages of design would enable the designer to arrange for local stiffening in order to carry the loads imposed under such conditions.

As the operations of replenishing fuel, lubricant and water, and of adjusting the power plant, cannot usually be performed from the ground, it is mainly for these purposes that men climb on to aircraft. They treat axles, radius rods, exhaust pipes, and struts as platforms, and bracing wires, fairings, and the like as banisters. Apart from the question of unfair stressing, which has already been touched upon, the said objects are never really successful in these more humble capacities. Consequently there is every reason why proper handholds and footholds should be provided.

Whilst dealing with the question of replenishing petrol, oil, and water—

at present a rather long and highly inconvenient operation—a strong plea is put forward for larger filling and emptying apertures, and for their arrangement in less awkward situations. It is suggested that filling from underneath has many advantages, both as regards convenience and the avoidance of air-locks in pipe systems.

The deterioration which may take place owing to atmospheric conditions demands considerable attention on the part of the designer, apart from the specifying of protective processes. These processes include painting, varnishing, pigmenting, a special process for metal parts, such as "Coslettizing" and "Sherardizing," and the use of non-corrosive materials. Attention should also be given to drainage arrangements in planes and fuselages, the sealing of hollow tube members, axles and struts, and the general avoidance of pockets and corners where moisture would collect. This is particularly important in the vicinity of glued-up wooden constructions such as ply-wood, built-up ribs and spars. These rely upon the strength of the glued joint for their rigidity, which is materially affected by the action of moisture.

In this connection it almost seems desirable that covers for exposed parts such as engines, propellers, and open cockpits, should be included in the design, and provision made for their accommodation in the machine. These essential accessories are rarely available when required, and the tendency is to provide them as an afterthought.

6. Repairs and Replacements.

In view of the necessity of saving as much redundant weight as possible above that actually required to fulfil safety conditions in the design of aircraft, occasional minor accidents will inevitably occur when subjecting a machine to abnormal conditions such as landing in bad weather, or by forced landings in places with bad surfaces and obstructions.

To cope with such accidents it is necessary that the work of repairing machines should be facilitated as far as possible to avoid their being out of commission for unduly long periods, and to permit the damaged parts to be replaced without involving an excessive amount of work.

The designer can materially assist in arriving at such conditions by developing on standardisation lines throughout the design. It is encouraging to note that great advances have been made in this country during and even previous to the war, as regards rigging attachments, piping connections, bracings, etc., and generally the smaller parts which are common to most types of aircraft; but there is still ample room for further development in other parts, such as fuselage sockets, plane attachments, wiring plates, struts and fittings, to name only a few.

Even in the case of complete components there appears to be room for further standardisation, and in one case this has been taken advantage of to a very large extent by arranging the design of the ailerons, elevators, and rudders so that they are all interchangeable. Such advances reduce the quantity of spares required, which is a very important item.

Apart from standardisation of the parts themselves, the use of as few different sizes as possible of parts such as bolts, nuts, wires, fittings, etc., also reduces the spares difficulty, and at the same time reduces to a minimum the tool kit to be carried on the machine.

An advantage of standardisation especially concerning rigging attachments, which perhaps has been overlooked but which is considered to be of great value, is the fact that in making replacements the danger of substituting parts under the required strength is practically eliminated, as a part of incorrect size will not assemble on the adjacent fitting. It also has the advantage that in making new

fittings, or verifying the strength of an existing fitting, the load to which the part should stand can be picked up from a knowledge of the strength of the standards without involving extensive calculations.

Repairs can also be facilitated by reducing to a minimum the amount of dismantling or stripping necessary to enable the replacement or repairing operation to be carried out. Particular offenders in this direction are continuous longerons, fittings which require to be slid on a member from the end instead of straddling it, fittings secured by rivets, or other permanent fixings, parts built up in position, and welded or brazed up structures. Seaplane hulls and floats are also typical instances where repairs are very extensive operations, even for rectifying the slightest damage.

One of the greatest liabilities to danger in making replacements is the difficulty of determining the correct material from which the replaced part should be made, and it is contended that in cases where high tensile steel is used some provision should be made to enable the material to be readily identified. Indeed, any case of employment of a special material, not readily distinguishable at sight from that commonly used, calls for such treatment.

The author remembers one case where the designer had used a bolt of the standard dimensions, but in view of the excessive load which came upon it he had resorted to the use of a higher grade material to obtain the necessary strength. It happened that elsewhere on this particular machine there were standard bolts of the same size but of standard material. Naturally, at a later date, after overhaul, the bolts became mixed, and the structure collapsed in the air with fatal results.

The provision of instructional notices containing information as to piping and wiring diagrams, rigging dimensions, doping schemes, and warnings generally, placed in convenient positions on the machine, is invaluable to those who have to attend to repair and maintenance generally, and it is strongly urged that this practice be encouraged by the designers in order that their designs shall not be abused.

DISCUSSION.

Brigadier-General R. K. Bagnall Wild (Chairman of the Society) remarked that as Major Bishop was in the A.I.D., as he also was, it was a little difficult for him to start the discussion on the Paper. He thought the Paper gave them a very useful lesson as to what was possible, and showed that they could by careful construction and design produce aircraft at far less cost than during the war, and that they could produce it with safety—safety in flight. Such precautions as putting peepholes to see that struts were into their sockets and so forth were essential to safety. He suggested also that those who sold machines and engines should make a stipulation that no other spare parts should be put into engines than those supplied by the maker; that was a most important point. There was a temptation that might occur in some cases, when giving joy rides in the summer round the coast, to use any part that could be got locally, and they were not always correct. He did not agree that probably the majority of this country's output of aircraft would be exported. He thought a proportion would be exported, but that the majority would be used in Great Britain for services all over the world, and even if they did not start from Great Britain that they would be under British control. The lecturer advocated careful economy in machinery, material and labour, and in order to facilitate this he (Brigadier-General Bagnall Wild) suggested that the designer should be supplied with a list of material and sizes of material prepared by the buyer and approved by the shop manager, as being in the first place readily obtainable both from the point of view of delivery and cost, and secondly as being suitable for the machine tools and labour existing in

the shop. As regarded welding, he would like to point out a case of German welding. In a German machine it was found that the main tubular structure of the fuselage supporting the top planes depended entirely on the weld. This machine was flown by British pilots in England. The weld was in tension and subjected to bending. Several cases of failure were investigated and it was found that the heat necessary for the welding had destroyed the properties of the tube and that it could not be restored to a proper condition by any heat treatment. These machines caused serious accidents, and as a result pilots were forbidden to fly them. With regard to periodical inspection, to look after leaks of petrol, water and the air system, he did not like the word "prevalence" used by the lecturer, and he did not think it should really be used at the present time, because designers so looked after the installation system that leaks in petrol, oil and water systems ought not to occur, provided there was adequate facility for inspecting those pipes, and provided the ground engineer, in the case of civil aviation, or the service mechanic or service officer responsible was fully competent for his job. The packing of machines had given a lot of trouble. A large amount of money could be saved by more careful attention to packing and transport. They did not know enough about packing for the tropics. They had sent out propellers to India and other places and lost them, simply because they had not known how to pack them properly. They had packed them in tin cases, sealed up, but that was no good, and they had tried packing them in other ways, but they had a lot to learn in that and similar directions.

Sir RICHARD GLAZEBROOK congratulated Major Bishop on his lecture and the information he had put before them, which would be of great value. He would limit his remarks to one particular point, the standardisation question. He thought those present would agree that the time had not yet come when they could standardise aircraft as complete machines, and to attempt to do so would be to retard progress to a considerable extent, but there were many parts that were common to aircraft of the same class, and those parts could with advantage to everyone concerned be standards. They had learned much during the war as to the value of standards. His own work in that direction had been concerned chiefly with gauges; it was his duty during the war to pass the gauges that were used not only in the A.I.D., but elsewhere, and he had learned something about gauges and their requirements. When they first began to attempt to standardise for the A.I.D., and indeed generally, they were met with the fact that there was no such thing as standardisation of aircraft parts. Taking the case of screw gauges and screws, bolts and nuts, every engine and every designer had their own sizes of bolts and nuts instead of adopting some standard dimension or series of dimensions. Anything that seemed to be the best for the moment to the individual designers of engines was put in, and the rush and press was so great that it was necessary to accept these, although it was realised at the time how much that interfered with production and how much the difficulty of getting the necessary gauges delayed supply. Some engines were of French and other foreign makes and with these millimetre screws were used, therefore if they wished in the engines built in England to make use of the French designs millimetre measurements had to be used. Even those millimetre screws were not standard. There was at the time recognised in France a series of standard millimetre screws, but it was not in regular use, and when English screws were used, instead of adopting the British standard fine or British standard Whitworth thread, and selecting screws of diameters for which gauges were readily and easily supplied, designers had got into the habit of adopting any screws, sometimes 1/16th inch or 1/32nd inch bigger or smaller than the standard size. The experience thus gained led him to appreciate fully the great importance of standardisation of parts. He would like to impress on designers of engines especially that much was to be gained in all directions by realising that there were a series of standard threads available, the British Standard Whitworth, the British Standard Fine or the B.A., which covered nearly all the wants of engine designers and aeroplane builders; the general

adoption of these would reduce expense and simplify construction to a very considerable extent. He knew in later days, owing to cordial co-operation by Major Bishop and Brigadier-General Bagnall Wild and others, the number of screw threads used in engines was enormously reduced and production considerably increased as a result. The men concerned with design and work at the present time should utilise to the full the series of screw threads and other parts that had now been standardised by the Engineering Standards Association, and if that series was not convenient or suitable they should, before adopting something different, bring the matter to the notice of the Committee of that Association which was dealing with the question and ask to have modifications considered and if possible standardised.

Major S. HECKSTALL SMITH said he knew a great deal of the work Major Bishop had done on the subject of standardisation, and the results had been very helpful. It was a little difficult just now to think of standardisation in relation to aircraft, because it was difficult to see that there was going to be any aircraft. It was almost a crime when one thought that with the millions of pounds that had been spent in bringing flying to the state it had reached that there should be a period now which was going to make the work of designers so difficult, and one of the most important subjects would be this question which Major Bishop had raised. It looked very much as if we were going to suffer on this and other subjects in connection with the design because there was no work which had been given to the designers to help them along towards producing commercial aircraft. Hardly any commercial aircraft existed in England to-day, although there were a few machines which showed some prospects at this early stage of becoming commercial aircraft. Perhaps some of the designers who had been engaged on machines which looked like promising aircraft might not agree with him, but they had to look at the question a little further ahead. General Bagnall Wild said aeroplanes and engines could be bought cheaper now than during the war, but he hardly thought he meant that, or possibly he had not tried to buy engines as he (Major Smith) had. The price was prohibitive, and the reason was that there were no engines being made. There was no encouragement for the firms who were capable of making engines—the firms with the necessary machinery and plant—because they were crammed full making motor cars which were profitable, and they were dropping away from the manufacture of aircraft engines. Without the manufacture of engines aircraft designers could not produce designs of aeroplanes, because they must start with the engine. Everyone concerned should endeavour to press the question to an issue at the earliest possible date. Some of them belonged to the Aëronautical Society, others to other engineering societies, and others might be able to join the Aerial League which General Seely was organising, as he mentioned in the "Times" on Friday, and it behoved everybody, especially in that Society, to take every step in their power to call for some discussion on the very essential point of aeroplane engines, because unless they got to some point of standardisation in engines they would be left stranded or depend entirely on foreign engines. They should be satisfied with a few sizes, say, 100, 400 and 800 h.p., or other ratings which might be agreed upon, and thus reduce the number of engines existing to-day. They should then impress upon the Government the necessity of producing or starting at this stage the design of engines of those h.p.s and giving to designers an encouragement to standardise a few engines and consider the possibility of supporting those designers with sufficient money to build experimentally those engines, so that this country might not be left in another two years' time without any engines at all, which was the position that was gradually coming and was well in sight to-day. That was the most serious situation with which aeronautics had ever been faced.

Captain F. M. GREEN said he had listened to Major Bishop's paper with great interest, and he thought he had raised certain points which are of great

importance to the development of aeronautics which have not been discussed before at meetings of the Society. He had quite rightly laid great stress upon the importance of good drawing office work, and as he entirely agreed with him in this matter he hoped that the importance of the drawing office will be more generally understood.

At the present moment the pay of draughtsmen is wretchedly bad and consequently good men do not stay in the drawing office longer than they can possibly help. As a consequence of this the standard of drawing office work is not nearly as high as it ought to be. In order to be a capable draughtsman, it is necessary to have had not only a thorough technical training, but also a thorough shop training and considerable experience of drawing office routine. A large number of draughtsmen start in the drawing office as boys, and never go into the shops at all. This sort of man produces drawings which are admirable as far as draughtsmanship is concerned, but nearly useless in the shops. He thought the International Correspondence School encouraged this sort of draughtsman.

A properly trained draughtsman should have a very good idea how the details should be produced and also a very fair idea of the time that should be taken in the various processes. It is specially important that he should have had training in a foundry as well as in the machine shop, while a few months spent in the stamping works is itself a great value.

The amount of trouble that is caused in the shops by bad draughtsmanship and incomplete drawings is really surprising. What is even more surprising is that it is looked upon as a necessary evil by almost everyone; the obvious remedy of raising the standard of the drawing office seems never to be considered. With a higher standard of the drawing office not only would the general design be improved, but the cost of all work, experimental work in particular, would be greatly reduced.

The value of an aeroplane depends very largely on the excellence of its details, and the detail work largely results on the skill or otherwise of the individual draughtsman. During the war there have been quite a number of well-trained, intelligent draughtsmen who have specialised on this sort of work, with the result that the aeroplane detail work has been gradually improving, helped of course by the experience on the faults of previous designers. At the present moment, he thought he was quite right in saying, there is almost a total stoppage of design, with the result that draughtsmen with valuable training are drifting away from aeronautical work and finding employment in other directions. This was, he thought, a disastrous state of affairs, and it is inevitable that if aeroplanes were again needed in a national emergency, then experienced draughtsmen who we should have to employ would be certain to make inferior designs, resulting from their lack of experience. The only way he could suggest to avoid this is that the Air Ministry should authorise and pay for the design and construction of a reasonable number of experimental aeroplanes. Even now it is somewhat too late to do this, as a large number of good men have already been lost, but he did hope that the importance of time will be realised and that this policy will be carried out before all the experienced men have undertaken other work.

Major Bishop's point with regard to the wear and tear on aeroplanes due to handling and erecting is important. Much too little attention has been paid in the past to the ease of assembling an aeroplane. The fittings that have to be undone should be made as few and as simple as possible, and the various parts should be made suitable for transport. On the other side of the question he thought it is time that air mechanics, when working on aeroplanes, should be unmilitary enough not to wear hob-nailed boots.

Major D. H. KENNEDY said he had a high respect for the work Major Bishop had done in connection with standardisation. Now was the time, after the stress of war, for aeronautical people to get together, and go in carefully for detail

standardisation. They had several classical examples of the need for it during the war. One case which he would quote gave them a lesson which he would like to see driven home in the proper direction. The war commenced in 1914, and so far on in the war as 1917 it was found there was the greatest difficulty in obtaining supplies of copper tube. Both aircraft and engine firms were crying out for it and bombarding Adastral House with inquiries, and officers were being sent in motor cars to copper tube manufacturers, but the results were extremely meagre. It was found that copper tube, like other items such as screws, had been left without regulation, and the copper tube firms—most of them in Birmingham—were provided with large numbers of orders, which were of this kind; a firm would get an order for 50ft. of copper tube 1⅛in. external diameter and 19 gauge, and another order for copper tube ⅞in. internal diameter and 22 Whitworth decimal gauge, and another order for copper tube expressed in terms of metric sizes, and there was no unanimity with regard to the thicknesses required. Using the ordinary standard gauge, they were asking for every gauge from 10 to say 30, and the books of about a dozen firms in Birmingham revealed the fact that there were about 650 different sizes on order. The Air Board then acted very promptly and within six weeks got out a list of standard sizes of copper tube and found that all the requirements for aircraft and engines could be satisfied with practically one standard gauge and two or three other permissive gauges. The Air Board, fortified by their moribund lady friend, D.O.R.A., were able to insist upon the standard sizes being used, and they filled the Birmingham copper tube manufacturers up with orders for standard sizes and told them to scrap all the orders for non-standard sizes. But the question was how, without D.O.R.A., the work done by the Engineering Standards Association in producing standardised details, could be made effective. It was not much good appealing to individual designers. There must be co-operation between designers, and he thought the only avenue through which that could be obtained was the body which was referred to as the S.B.A.C. They should give a strong lead on this matter of detail standardisation. The Germans had increased their production during the war by standardising engines, and excellent co-operative designing work was done on the other side of the Atlantic which produced the Liberty engine. He thought the moral was quite clear.

Mr. A. J. Sutton Pippard said he sympathised with Major Bishop in his desire for facilities for inspection, but he thought if some of his proposals were carried out the extra complication involved would outweigh the advantages gained. He understood the Author to suggest that fairings, cowlings and trailing edges should be detachable, and that the chassis should be made to divide into its components instead of making the solid V, which was the usual type, also that the aileron king posts and elevator king posts should be detachable. It was important that the king posts should be detachable from the point of view of packing, otherwise the space taken by wings and tail planes was so great, owing to the depth of those members, that shipping costs became very excessive. The Author had shown a machine on the screen in which the ailerons, elevators and rudder were interchangeable. There were two other machines constructed during the war in which this was done, but he thought there was serious trouble to be anticipated if the idea were not used very carefully. The principal object of those surfaces was to ensure stability and controllability, and only in very exceptional cases would the varying demands of stability and controllability be compatible with interchangeability. If too much stress were laid on the importance of interchangeability there would be a temptation to sacrifice the infinitely more important qualities of stability and facility of control.

Mr. Folland referred to the question of producing drawings for proper manufacturing lay-outs. The lecture appeared to be based on the proposition of aeroplanes made in mass production, but the orders at present were in such small quantities that it did not pay to make a very elaborate lay-out. He had

made an interesting comparison with the design of two machines, one made on the American basis of piece parts which involved over 1,800 drawings, which took about four months to prepare, the other of a similar type, done on an experimental basis, the number of drawings being 200, and the time taken on them two months. The design cost in the two cases was approximately in the ratio of 3 to 1, staff in each case being equal. When one considered such a proposition as the British aircraft competition for a large size machine, which had a very doubtful coefficient of utility and of which the cost per ton mile had apparently never been studied, it would be realised that one could not spend a lot of money on a type that was not going to be a commercial proposition even assuming that it was accepted as a winning machine. The lecturer pointed out the advantages of built-up sheet metal brackets. He (Mr. Folland) had always looked upon the sheet metal bracket as a phase in the development of aircraft on an engineering basis. Drop forgings had not been studied in the past as they should have been, little care being taken to prevent eccentricity of stamping and sliding of dies, and they had always been looked upon as the old rough forgings such as were used for automobile work.

When one considers the numerous parts and operations necessary for the built-up bracket one realises more fully the dangers of faulty construction due to its numerous operations, possibly the missing out of one or more annealing operations. For example, take a built-up plate bracket of five different plates, this would necessitate five press tools, five piercing tools, five blanking and piercing operations, annealing after blanking and piercing, right and left hand bending tools, annealing after bending, assembling plates together, rivetting or tack welding plates in position, sand blasting before brazing, fettling up after brazing, trueing up before sending to inspection, as compared with the drop forging which probably needs three forming dies, one shear die, heat treatment after stamping, two milling jigs, one box drilling jig, and probably a boring jig.

He thought that on the whole where reliability is necessary the drop forging would be by far the better product in this direction when aeroplanes become a mass production job, than the built-up plate job which passes through so many stages before it becomes a part of the aeroplane.

Captain W. H. SAYERS said the Paper gave an impression that aeroplane designers had not agreed about standardisation in the past, or had not been able to carry it into effect. It was only fair to put a statement of the war-time aeroplane designer's position. For three years he was in charge of the design department of a small Service experimental station with a personnel of 120 men. It designed and built seven different types of experimental machines. They were hoping the whole time that some of their machines would come into production, but actually they did not. He did a great deal while on that station towards standardisation. One machine had steel tube interplane chassis and drift struts, steel tube rudder posts, and steel elevator rear and front spars were used. In that machine there were two diameters of steel tube of two gauges, one piece being of 22 gauge and the rest 17. There were only four standard tube terminals in the machines. He was in a fortunate position in one respect. He built his machines and then the drawings went to the Technical Department for stressing, and they said the machines were fit to fly in every case, and then they tested them.

He was asked, in this case, why he had wasted so much weight, and he was told that if he had put in steel tubes of the correct size at least five per cent. of the total weight would have been saved. His own impression was that he could have saved more. He was told that if that machine went into production they would take care that five per cent. was saved, though it would have taken twice as long and cost 50 per cent. more. By standardising, a certain amount of weight was inevitably thrown away. But one knew that if the weight were cut down

to the minimum it would not make any serious difference to the production cost, as the production was always so different from the design that it did not really matter whether one standardised or not. That was one of the reasons why the aeroplane drawing office had always been run on the lines of an experimental drawing office and not a production drawing office. He thought the fault lay nearer the A.I.D. than the designers. There was an enormous lot to be done in regard to standardisation of engine installation. He started trying to make aeroplane engines run in 1910, and found the lack of standardisation even in those days a great drawback. If an English engine were taken out of a machine and one attempted to replace it by another engine, ostensibly of the same type and size, one had to spend anything from two to ten hours bending and adjusting water pipes and connections to make it fit. There was no standardisation even in the same make of engines. Of the seven machines he designed only two went out of the shop with the engines for which they were designed. Of the other engines, two would not go into the bearers built to the Air Ministry installation drawings. The aeroplane engine builders should have standardised engine installations as a whole, and make them to fit a standard set of back plates.

The AUTHOR, replying to the discussion, first dealt with the need of financial assistance to the industry at the present period. He could not agree with General Bagnall Wild as regards the prediction of the sphere in which the future of aircraft will lie, but considered that wherever this may be the necessity of packing will always occur, even if only from the point of view of dealing with spares. He agreed that it was necessary for drawing offices to be provided with lists of available materials and standards generally, through the medium of the buyer, who should be thoroughly conversant with current markets. The reference to "prevalence of leaks" in the Paper was made to emphasise the necessity of making such provision whereby such defects could be eliminated. There is no doubt that a large number of engine failures in the air in the past were traceable to such leaks. He was pleased to hear Captain Green agreed with his remarks on the status of draughtsmen, and his own experience had been that directly a man got useful he left owing to the inadequacy of the pay. With regard to Major Kennedy's remarks on standardisation, he thought the case of copper tubing was but one of many dealt with during the war, but incidentally it was a particularly good example, inasmuch that it eliminated the chaotic state of affairs which existed before the standards were adopted. He was afraid that it might be difficult to enforce the strict adherence to standards even after they were agreed unless some commercial D.O.R.A. replaced the present one. The reference to detachable fairings was not intended to apply to struts, where there was no occasion to have them easily detachable, but rather to such items as turnbuckles, connections generally and the like, where adjustments and inspections had to be carried out. Detachable trailing edges of large planes had already received attention in the case of one machine. Mr. Pippard's reference to the interchangeability of controlling surfaces was not understood, as the aero-dynamic quality of the machine referred to was unaffected by the introduction of the standard controlling surfaces. If rudders, elevators, and ailerons could be so arranged as to be actually interchangeable, he considered this to be a valuable asset, not only from an interchangeability point of view, but also to assist production, as the more similar parts one has in a design the easier it is to produce. Concerning drop forgings, he did not wish to say they should be barred from use, but rather that in the majority of cases it was simpler and cheaper to adopt the sheet metal construction. He certainly agreed that the drop forging may be developed eventually, but its assistance to aircraft design in the past had not been very great. He attributed this to the inadequate state of affairs in the stamping industry, where acceptable tolerances could not be worked to and where the care of the material was so neglected. When forgings were tried early in the war, tolerances of 1/16in. to ⅛in. were required, which necessitated additional machining to keep the weight

down. Also no guarantee of materials could be given owing to the utter disregard of the effect the stamping had on the state of the material. In reference to Captain Sayer's remarks, the Paper was not in any way intended as a dig to designers' present practice, but rather to put before them a plea from those who had to work on the aircraft in order that their requirements may receive consideration at the time of design. He pointed out that the relative merit of the various suggestions in the Paper must be judged by the designers, and it was entirely a matter of degree as to the extent of their embodiment in the design. It is obvious that no designer would design entirely from the point of view of evolving an ideal machine from a packing point of view, but he should bear in mind that machines do have to be packed, and if he can simplify the operation he should undoubtedly do so. For the ideal design a happy medium of all characteristics should be aimed at.

The CHAIRMAN congratulated Major Bishop upon his extremely practical Paper. The remarks of Major Heckstall Smith and Captain Green were directed to the necessity of keeping designing and experimental staffs in full vigour. The constructors were fully alive to that necessity. Only recently his Society made representations to the Air Ministry, somewhat on the lines that had been indicated, asking that steps should be taken to give out experimental orders in order that the organisations built up during the war should not be dissipated. There were bodies coming into existence which should see that the public were educated on the question of the Air Service and get influence brought to bear on the Government, which after all had to decide these questions. It would be a mistake to try to standardise military types of machines. He agreed with Sir R. Glazebrook and Major Kennedy as to the need for standardising the detail parts as far as possible. He did not see why the work done by committees and sub-committees of the Engineering Standards Association in regard to standardisation during the war should not go on now. Standardisation would have to be by agreement, but he hoped agreement would be more efficacious than even D.O.R.A. was. The Society of British Aircraft Constructors would see that the standards proposed by the Committees of the Engineering Standards Association were adhered to. The specifications issued by the Technical Department of the Air Ministry was a most valuable contribution to the work of design and construction. The problems of military aircraft were very different from those of civil aircraft. First cost and maintenance were bound up closely with performance. In the military machines, speed, climb, manœuvreability had to be secured, and those points came before consideration of cost. But even so, there were points brought out by the lecturer which must be increasingly borne in mind, as expenditure on military aircraft would be closely scrutinised. Inspection would become more and more important as the demands for performance became more exacting. He paid tribute to the great work done by the Inspection Department in the early days under the late Colonel Fulton and afterwards, through the main period of the war, by their Chairman, General Bagnall Wild. The department had always set a high standard of workmanship, and British aircraft construction owed much to its work. Storage, packing and transport were as important for military machines as for civil aviation. Depreciation of spares had been an expensive item in the past, and varying climates and very difficult conditions had to be provided for.

With regard to first cost of civil aircraft, we had to go into the world's markets to obtain our orders, and we were therefore faced with severe competition. It was important that British construction should always stand by its high quality, and that nothing should be sacrificed in that construction, but quality of construction meant greater cost of construction. Though that seemed in the first instance a disadvantage, he believed the reputation we had for the excellence of our workmanship would keep us in the foremost place. The lecturer gave suggestions for bringing down the cost by careful attention to

the preparation of designs and care in manufacture. At this transition stage one could not think of standardisation, but it would certainly come in the case of civil before it did in the case of military aircraft. In the back parts of the world, and on cattle ranches and other curious places without workshops at hand, where machines and parts would have to go, simplicity of handling was very important, and simplicity of design must be adopted because of that fact. A simple commercial engine was required that would be reliable and economical to run. He thought they were all in agreement with Major Bishop as to the need for foolproof aircraft. He proposed a hearty vote of thanks to Major Bishop for his excellent Paper.

NOTE ON AN EMPIRICAL FORMULA FOR AEROPLANE STRENGTH.

BY A. J. SUTTON PIPPARD, M.SC., A.M.I.C.E.

The decision as to what strength shall be given to the structure of an aeroplane is made as a result of previous experience. It is well known that it is quite impossible so to design the structure as to render it unbreakable under any condition of flight without increasing the weight to such an extent that the aeroplane is useless as a flying proposition.

The result has been that load factors have been specified for different types of aeroplanes such as experience has shown will render the structure safe for any reasonable treatment in the air.

The principal factor to be fixed is that for the case when the centre of pressure is in its most forward position. Once this is determined the remainder of the structure can be designed consistently with it.

The value of this factor will depend primarily on two conditions—first, the speed which the aeroplane can reach in flight and, secondly, the rapidity with which it can be manœuvred.

The first of these conditions will be governed by the weight-horse-power ratio of the aeroplane and the second partly by the dimensions of the craft.

The writer has endeavoured to summarise the result of war experience in a formula for the front truss load factor and has found that if

N = the horse-power per 1,000lbs. gross weight of the aeroplane,
L = the over-all length of the aeroplane in feet,
F = the required factor when the C.P. is in its most forward position,

Then

$$F = 8\frac{\sqrt{N}}{L} + 3$$

A list is given of various aeroplanes showing the value of F calculated from the formula and also the actual strength required or obtained.

In some cases when the specified strength is not known but actual destruction test figures are available, these latter have been inserted and are printed in italics in the table.

It will be seen that taken on the whole the results are very closely in agreement.

Two or three of the latest aeroplanes show values of F higher than the factor called for. This is due to the very high ratio of engine power to weight and the consequent large speed range obtainable.

The formula is of course empirical and must be considered only as a summary of past experience.

The writer is curious to know, however, how other aeroplanes not included in the list fall into line and would be glad to hear opinions from designers.

NOTE.—It should be remembered that destruction tests always give higher results than calculations.

In comparing *F* therefore with the actual load factor, where the latter is given as a destruction test figure, it is necessary to correct, and the writer has found that 6/7ths of the destruction test factor gives approximately the calculated factor.

TABLE.

Type.	W.	H.P.	*N.*	*L.*	*F.*	Spec. or actual load factor.
D.H. 4	3313	270	81.5	30.67	5.5	*6.7*
A.D. Boat	3317	210	63.3	30.0	5.2	6.0
Bristol Fighter	2783	253	91.0	25.75	6.0	*6.2*
Fairey Campania	5416	360	66.5	44	4.5	4.0
F. 3	13400	700	52.2	49.2	4.2	4.0
H.P.o-400	13200	720	54.6	62.9	4.0	4.0
F.E. 2 D.	3430	250	73.0	33.2	5.1	*5.6*
B.E. 2 D.	2200	100	45.5	28.0	5.0	
S.E. 5a	2038	210	103.0	20.9	7.0	7.0
R.E. 8	2592	160	61.7	27.9	5.25	*6.2*
Sopwith Pup	1234	84	68	19.3	6.5	*7.4*
,, 1½ Strutter ...	1910	126	66.0	25.25	5.6	6.0
,, Camel	1454	128	88	18.67	7.0	*6.9**†
,, Dolphin	2068	210	102	22.25	6.7	7.0
Vickers Vimy	10244	506	49.4	42.67	4.4	4.0
,, ,, ...	11500	720	62.3	42.67	4.5	4.0
Handley V.1500	26000	1440	55.4	64	4.0	4.0
D.H. 10	8700	800	92	40.5	4.9	4.5
Kitten	586	32	54.6	15.6	6.8	7.0
Sopwith Snipe	2028	230	113.5	20.2	7.6	7.0
Tarrant Triplane	45000	3000	67	73.2	3.9	4.0
Basilisk	1820	320	176	17.5	9.0	7.0
Nighthawk...	2005	320	160	18.5	8.5	7.0
Snapper	1950	320	164	20.75	8.0	7.0
Snark	2100	320	152	20.5	7.8	7.0
Avro Puma / Schneider Cup	2045	250	122	21.33	7.1	7.0
Austin Whippet	800	40	50	16.0	6.5	7.0
B.A.T. Baby	1200	170	141	18.0	8.2	7.0
Blackburd	5700	352	62	34.9	4.8	5
Fury	32000	1795	56	63.0	3.95	4
Martinsyde F. 3	2261	285	126	25.9	6.5	about 7
Phœnix Cork	11200	704	63	48.6	4.3	4
Sage 4c	2750	200	73	32.5	5.1	6
Westland Limousine ...	3340	270	81	28.5	5.5	5

* Strengthened at a later date.

† See Paper by the Author in "Engineering," January 30, 1920.

REVIEWS.

Aviation. Theorico-Practical Text Book for Students. Benjamin M. Carmina. MacMillan and Co. 11s. net.

It has been said by an eminent Ambassador that Americans are hard to understand. After reading the book under review one American is impossible, in all senses of the word.

"Aviation" is the grandiloquent title; "Theorico-Practical Text Book for Students" the sub-title; and Benjamin M. Carmina the author of one of the most amazing books on aeronautics published since the days of Dædalus and his son. On the paper cover of this book we read:—

"There has long been the need of a book on aviation which should give the theory without sacrificing the practical end. It is just this need which Mr. Carmina seeks to fill."

This seeking, this "theorico-practical text book," is the philosopher's stone of aeronautics and its discovery afresh by some over-convoluted genius provides a new foundation stone for the coming museum dedicated to the follies of the air. Mr. Carmina and his book will by no means have a subordinate place in such a museum.

To the men who have had good experience "practico or theorico" this book is "a kind of giddy harumfrodite—practico and theorico too"—to chuckle over, but to the eager young student, and there will soon be many, who is now growing up to live in an element strange to our forefathers, this book is positively dangerous. There is no other word to use and it is a pity there are not words sufficiently strong in the English language which once used about a work of this kind condemn it for all time. We will quote a few specimens of the author's ideas on aviation. The italics are the reviewer's.

"The fuselage is usually made in a square section, built box girder fashion and has a fineness of 7."

"Fineness is the ratio of the length to the width of a *streamlined* body. *It is proportional to the velocity.*"

"The drift wires have the object of strengthening the centre section against the pressure of the air when the machine is in flight, *and the anti-drift wires are necessary to counteract the tension of the drift wires and to keep the centre section straight and rigid.*"

"In a biplane, or multiplane, the additional bracings are: The interplane struts *which hold the wings apart.*"

"Propeller and mystery are synonymous. In our year of grace 1919 nobody knows exactly what a propeller is."

(The author follows with 16 pages of mystery and imagination about propellers which vie with a rather more famous American author's tales on the same lines.)

"An increase in diameter really means an increase in the efficient part of the blade, as the further out we go, the smaller we find the angle of pitch and the greater the thrust-drift ratio and consequently the greater the efficiency."

(The farther out we go the lower the efficiency, of a given propeller, as a matter of cold fact.)

"Metal propellers have the advantage of cheapness as compared with wooden propellers."

(Not in Great Britain at any rate.)

The whole propeller chapter, where it is not mysterious or imaginative, reeks of marine propeller practice.

" . . . The extreme fluidity of the air. . . ."

This is one of those phrases of ignorance which ought to live for ever in aeronautical history.

" In regard to the shape of the curvature of cambered planes the best suited is the parabolic curve, with its highest point near the front edge. This parabola, as soon as struck by the air, pushes it downward with *constant vertical velocity*, without interference with the following masses of air, in this way increasing the lift and decreasing the drift."

This will give the inquiring student something to think about.

" The plane must be light and strong in the meantime, and we could not build a plane *immensely long* without increasing its weight beyond the limit *imposed by the aerodynamical laws*, for the reason that the volume, and therefore the weight, of a body increases as the cube of the linear dimensions and the surface as the square of the dimensions, and *consequently the relations between weight and surface would be completely disturbed.*"

This is one of those statements which make a reviewer wish he were not reviewing for a serious publication. The present reviewer, however, might be permitted to remark that he now understands the meaning of " poor relations," and why they are so disturbing. It must be the air.

Enough of this superlative farrago of nonsense has been quoted to reveal, to the man who knows, the character and the danger of the book under review, and it is hoped that the " theorico-practical " student will also be able to take warning. If he does not, the following extract from a lecture delivered before the Aeronautical Society of New York in February, 1911, by the author and quoted in his book may drive the lesson home:—

" My study of aeronautical science, or rather my battle with the text books on aerodynamics, has been the longest, hardest mental struggle of my life.

" Contrary to the rule for the mastery of knowledge, the more I studied, the less I knew; but, luckily, the less I knew, the more grew my desire to know. And I studied all the aeronautical books I could get hold of and written in the languages I understand, but the result was simply the twentieth century re-establishment of the ancient kingdom of Babylonia right between my brains, and an infernal dance of angles, sines, cosines, tangents and coefficients, which brought about such a tremendous pressure against the centre of gravity of my brain as to threaten to unbalance it and to render myself fit for a straight flight into an insane asylum."

The mental struggle of the author's life has culminated in " Aviation," and it is to be sincerely hoped that he will have no more such struggles. They must be very exhausting. The author candidly admits that the more he studied the less he knew, and this book reveals the rather curious fact that he has studied more than the average writer on aeronautics.

The book contains a number of definitions which are among the very best of their kind. Here we find a definition of Algebra, coming in its true alphabetical sequence between Air Speed Meter and Altimeter; here we get definitions of Banana Oil, Blow Torch, Metric System, and Trigonometry among others in this book entitled " Aviation."

As a final word it is a great pity, to say the least, that a publishing firm of the eminence of Messrs. MacMillan should have lent the weight of their name to such an effort on the part of Benjamin M. Carmina. The price is eleven shillings

net. He who buys will be wasting his money, unless he is prepared to laugh. And we can get much better humour for eleven shillings, nowadays, in periodical form elsewhere.

J. L. P.

Streamline Kite Balloons. Captain P. H. Sumner, R.A.F. Crosby, Lockwood and Son. 10s. 6d. net.

Although the use of captive balloons for war purposes dates back now over a century and a quarter, modern types of kite balloon are essentially a development of the late war. For one hundred years after the first use of a captive balloon for military observation practically no development at all took place. In 1896 the German Drachen balloon was evolved, which, though a vast improvement on the captive spherical, was yet a long way behind the types which we have at the present day. Nevertheless, up to the outbreak of war, no sufficient reason appeared to have existed to stimulate further development, so that at the beginning of 1915 the Drachen still remained the only improvement which had taken place in balloon construction since the days of the first use of a captive spherical by the French in 1794.

The complete story of the work done by balloons during the war, both on sea and land, remains yet to be told, and up to the present very little information has been made public either about the construction or operation of balloons, yet the modern kite balloon is a war product even more than the airship or aeroplane. It is the more to be regretted, therefore, that those who took part in its development have not so far made any public record of the work which they carried out. Such information as is given in technical articles and books is usually very meagre and considerably out of date. In this connection it is interesting to note that in a recently published textbook on aerodynamics, written by a gentleman of considerable eminence in the aeronautical world, the only particulars given of kite balloons were some five years old and a great deal of his data referred to types which were never developed to a practical working stage.

Whilst Captain Sumner deserves credit for compiling a certain amount of information on balloons, it is to be regretted that he has given his book such an ambitious, and to a great extent misleading, title. The impression left on reading through the book is that it is the work of an author who, whilst having considerably more detailed knowledge of the kite balloon and its construction than the seeker for information who is expected to read the book, has failed to grasp properly the technics of applied aerodynamics upon which the explanation of observed aeronautical phenomena depend, and upon which any progress in the improvement of design of kite balloons or any other aircraft must be based.

In his introduction Captain Sumner gives a short history of the kite balloon during the war, which history has the grave disadvantage that the facts are not stated in chronological order; but as very few dates are given, this is not apparent to the general reader. At the end some highly imaginative statements are made on the subject of towing airships in which the author indulges in calculations from which it would appear that his knowledge of mechanics is not quite all it might be.

Chapter I. gives what might be described as a popular description of the Caquot M type balloon and illustrates the functions which the various parts are called on to perform, and this is followed by two chapters of the same character dealing with streamline forms and the static lift of a balloon. These chapters are typical of the book as a whole and one cannot help thinking that the author's scientific knowledge is of rather too superficial a character to warrant his attempting to write a treatise on aeronautical design, such as presumably the present book purports to be.

In a short chapter of some seven and a half pages the author attempts to deal with the subject of the application of aerodynamics to determining the equilibrium of the balloon, yet he only deals with the question of the static equilibrium of the

balloon in pitch, the first and simplest state of equilibrium that must be considered in balloon design. Even this is only treated in an elementary way, and if he intends that the diagrams should represent the components of the wind forces acting upon the balloon and its fins, a good deal of misconception is likely to arise in the mind of the reader. The term "longitudinal stability" has a very definite meaning in aerodynamics, yet we find in this book a chapter entitled "Longitudinal Stability," in which stability is only mentioned to the extent of pointing out that it is an essential feature for any workable balloon. The author appears to have no very clear ideas of the difference between equilibrium and stability. His criteria for stability appear to bear no particular relation to the actual facts of the case. But it is probably in the chapter on Wind Resistance that he has excelled himself in his mathematics. In endeavouring to arrive at an estimate of skin friction, based on Zahm's formula, the following remarkable passage occurs:—

"$L - .07 = 1/L\,.07 = 1/\log L \times .07$.

"Thus,

"1/log of $1.44 \times .07 = 1/.158 \times .07 = 1/.011$

"and delogarising $= 1/1.026 = .97$."

The remarkable feature is that notwithstanding such startling transformations, the author succeeds in getting the correct result.

The all-important subject of internal pressure in the balloon is dealt with in an extremely sketchy way and the main features are neglected altogether, attention being simply given to an approximate calculation of the tension in the envelope due to any given internal pressure, and even this calculation is only made by a most elementary method and would not be by any means sufficiently good for the purpose of investigating the tensions in the envelope of a balloon in flight.

When stating that the last three chapters, which to a great extent deal with actual details of construction, are the best in the book, this does not mean to imply that they are free from criticism, but the author does certainly give some idea, although not in a very complete manner, of the way in which the fabric work of a balloon is developed and set out for purposes of construction. He gives a table purporting to show the dimensions, cable tensions, equilibrium altitude, etc., of balloons of varying volumes without giving much information as to how the figures are obtained. It appears from examination of the table that he assumes ratios between the weights of balloons of different sizes which are certainly very much simpler than actually exist.

In his final chapter the author refers to meteorological balloons and indulges again in calculations which are open to criticism. The book is followed by an appendix which is half the size of the remainder of the volume and which contains a most curious collection of odds and ends, a number of which do not seem to have much bearing upon balloon work at all, such as tables of moments of inertia and section moduli of rectangular and circular sections, tables of the simpler bending moments and a number of other elementary mechanical tables and formulæ, definitions, tables of trigonometrical functions, logarithms, etc.

The appendix concludes with a glossary of technical terms associated with the modern kite balloon, copied without any acknowledgment from the Report of the Technical Terms Committee of the Royal Aëronautical Society. There is rather a suspicion that other matter in the appendix has been borrowed without acknowledgment in the same way.

In conclusion, it appears to be rather a pity that the author has attempted to record his knowledge of kite balloons in the form that he has done. Had he been content to write a short popular book to explain in general terms how kite balloons are made and operated, he would probably have been much more success-

ful than he has been with the present work. The impression left after reading the book through is that he has set out to do more than he is qualified to undertake. The book contains a number of statements which are scientifically inexact, and the amount of solid information of value for improving the design of balloons or for enabling existing types to be improved is practically nil. Anyone reading the book with a view to getting reliable information upon the subject of the design and stability of streamline kite balloons is likely to be disappointed.